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THE MINERALS *of* PENNSYLVANIA

NON-METALLIC MINERALS

By

R. W. STONE

Department of Internal Affairs
THOMAS A. LOGUE, *Secretary*

Topographic and Geologic Survey
GEORGE H. ASHLEY, *State Geologist*
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CONTENTS

	Page
Introduction	1
Asbestos	1
Barite	5
Franklin County	5
Fulton and Bucks Counties	8
Corundum	10
Feldspar	14
Garnet	16
Graphite, by B. L. Miller	18
Magnesite	23
Phosphate minerals	25
Cumberland County	25
Juniata County	26
Potash	29
Quartz-Flint	32
Rock salt	36
Crawford County	36
Elk County	37
Erie and Forest Counties	38
McKean, Potter, Susquehanna and Tioga Counties	39
Warren and Washington Counties	40
Quantity of salt	41
Titanium-Rutile	42
Vermiculite-Jefferisite	44
Miscellaneous minerals	46
Allanite	46
Beryl, Cyanite, Epidote	47
Gems, Greenockite, Tourmaline	48
Uranium-bearing minerals	49
Mineral resources reports	50

NON-METALLIC MINERALS

By R. W. Stone

INTRODUCTION

The Geological Survey receives many inquiries about the occurrence of minerals in Pennsylvania that cannot be answered by referring the inquirer to any readily available literature. In order to answer the questions an effort has been made by search in official and other publications and by field examination to assemble the information. The results are here presented.

ASBESTOS

In view of the variety of its uses and the number of manufacturers of asbestos products in Pennsylvania it is unfortunate that commercial deposits of this mineral fiber are not known in this State.

Asbestos is a trade term applied to any mineral which can be readily separated into more or less flexible fibers. The principal minerals known as asbestos are chrysotile, crocidolite, anthrophyllite, tremolite, and actinolite. All these have been found in Pennsylvania.

Chrysotile is a fibrous form of serpentine, with which it is always associated. This hydrous magnesium silicate occurs in fine silky fibers which usually are less than 1½ inches long. Fibers 5 to 6 inches long have been found. The fibers are flexible, have considerable tensile strength, and are nearly always white.

Crocidolite, because of its characteristic lavender-blue color, is often called blue asbestos. Its fibers are stronger but less resistant to heat than chrysotile. These are usually not over 1½ inches long. It is a soda-iron silicate.

Anthrophyllite is an anhydrous iron-magnesium silicate whose fairly long and usually rather brittle fibers have low tensile strength.

Tremolite and actinolite are calcium-magnesium silicates, which may occur in fine silky fibers of great length but of little tensile strength.

The uses of asbestos are too well known to need reciting here.

Asbestos has been found in several places in Pennsylvania, and it is reported that it was formerly mined. The following statement is from the Second Survey report on Chester County, C4, p. 350. "Asbestos is also an associate of serpentine. It has been mined on the farm of Jacob Sides, in Aston, Delaware County, and also in Upper Providence, where it exists in great abundance." This statement was published in 1883. Putting it with a statement that asbestos

was formerly mined at Rockdale leads me to conclude that the locality was at Rockdale, on Chester Creek, 3 miles southwest of Media, in Aston Township. No further information has been found and therefore may it be assumed that the quantity produced was small and the industry short-lived? A large quantity of amphibole asbestos was exposed about 50 years ago "on J. Smedley's land near Ridley Creek northwest of Media also north of the road leading from the Rose Tree hotel to Lima." This may be an over-statement.

Various references to the occurrence of asbestos are found in the reports of earlier Surveys. In the report of the First Geological Survey by H. D. Rogers there is only one indexed reference to asbestos, and that is merely the statement that asbestos occurs in the joints of a trap dike near Gettysburg. In the reports of the Second Geological Survey several references occur. In Minerals of Pennsylvania, vol. B, 1875 p. 116 is the longest statement:

> Chrysotile is found at Blue Hill, in Upper Providence township, in a seam in decomposed serpentine, the fibres are sometimes four inches long; in narrow seams of the thickness of a knife's blade to half an inch at Moro Phillips' Chrome Mine, in Marple township; also in Radnor township, Delaware County; in a seam of about half an inch in thickness it occurs in quartz in West Goshen township, Chester County.

At Blue Hill in Delaware County the writer found cross-fiber seams paper-thin up to 1/16 inch.

These township references certainly are indefinite. The name of the land owner or distance and direction from a village would help in relocating these occurrences.

In the Chester County report, C4, 1883, p. 78, we find "Asbestos, in flexible sheets like paper, has been found in Jackson's quarry." This seems to refer to the limestone quarry of Wm. Jackson on White Clay Creek, one mile west of Pleasant Valley and perhaps somewhere between Westgrove and Avondale. Perhaps serpentine occurs in the quarry.

In the Lancaster County report, CCC, 1880, p. 305, a discussion of copper ores in the southwest corner of Adams County includes the following statement: "On the bed of the 'Tape Worm' Railroad on Lewis Pittinger's place about ¼ mile N. E. from Washington Benchoff's house on the Emmettsburg turnpike the heading of an uncomplete rock cut displays a quantity of chrysotile. The rocks adjacent seem to be dark green argillaceous chloritic and epidotic masses * * *. Quartz abounds in these rocks and the fibers themselves seem to be largely composed of it."

In York County, according to report CC, 1877, p. 230, some asbestiform hornblende was found in Elicker's shaft. This was an exploratory shaft 15 feet deep in trap rock about 5 miles east of Dillsburg.

Most other references in the literature of 50 to 60 years ago are either indefinite as to locality, vague as to the mineral, or seem to indicate an occurrence in quantity only sufficient to identify the mineral.

Adams County. Concerning asbestos in South Mountain, Adams County, Stose[1] says:

> The best quality of asbestos obtained in the region came from a dike-like band of greenstone which crosses the Corls Ridge a mile north of South Mountain Sanitarium, just west of the county line. This asbestos is cross fibre and fills small gash veins about one-half inch wide in the greenstone. Although the fibre is green and silky, it is so short and interlayered with quartz that it has no commercial value. Other specimens of silky asbestos were obtained from the Baker prospect shaft in the small greenstone area 2½ miles southeast of the Sanitarium, at the western line of the county. Very thin veins of silky asbestos show in the Western Maryland Railroad cut near Charmian, in the southwest corner of the county. This has the appearance of a slip-fibre vein. Although the quality seems good the quantity at these places is very small and not of commercial value.

The writer's investigations of reported asbestos localities in South Mountain have resulted in finding the mineral in each instance, but in no case is the occurrence of more than mineralogic interest. Rare cross-fiber seams of chrysotile, perhaps intimately mixed with quartz, and less than half an inch thick, constitute the occurrence. The places where one can find soft silky fiber are so rare as to be almost nonexistant.

York County. The occurrence of asbestos at Accomac, York County, has been recorded:[2]

> Metabasalt occurs * * * in an area extending for a mile along the valley of a small stream leading to the Susquehanna River at Accomac. The metabasalt, or "greenstone," as it is commonly called, is a grayish-green to bluish-gray hornblende schist, blotched with green epidote, which forms knots on the weathered surface. * * * The rock has veins of secondary epidote and some asbestos, which is exposed just south of Accomac.

In August, 1934, the road from Highmount down the ravine to Accomac was widened and improved. Heavy blasting in the lower end of the ravine brought down thousands of tons of rock. Workmen on the road said they found one lump of soft-fiber asbestos and rolled it into a ball the size of one's fist. It, however, was not preserved. Search by the writer disclosed seams of cross-fiber asbestos 1/16 inch thick in epidote, and one lump of fibrous serpentine about 3 by 4 inches with which occurred soft, bluish chrysotile 4 to 5 inches long and 1 inch thick. This appeared to be slip fiber. In view of the great quantity of rock freshly exposed by blasting, this small showing of asbestos is insignificant.

That asbestos occurs at this locality has been known for many years and it is reported a manufacturer once offered to buy what asbestos the owner of the land might produce. No mining was done, however. All the evidence is against the occurrence of the mineral in commercial quantity.

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[1] Stose, Geo. W., Geology and Mineral Resources of Adams County, Penna.: Pa. Top. & Geol. Survey, C 1, p. 134, 1932.

[2] Stose and Jonas, Geology and Mineral Resources of the Middletown Quadrangle, Penna.: U. S. Geol. Survey, Bull. 840, p. 9, 1933.

Lancaster County. On the West Branch of Octoraro Creek at White Rock, where a narrow band of serpentine crosses the creek at a covered bridge, asbestos was discovered many years ago and a prospect opened. That work seems to have been sufficient to prove the non-commercial character of the occurrence. A few years ago stone was quarried and crushed here for road use and the larger exposure of rock reveals hard, stiff fibrous serpentine developed along slip faces, and rare seams of cross-fiber serpentine ½ inch wide.

Fibrous serpentine occurs in the same manner at the old Burkholder serpentine quarry on Gables Run 1½ miles south of Kirkwood in Colerain Township.

Asbestos is reported as occurring at the Gap nickel mines, but as these were last operated in 1902, the occurrence of minerals cannot now be investigated. Shafts are no longer accessible and other excavations are partly filled and overgrown.

Cornwall iron mine. According to W. O. Hickok, 4th, of Harrisburg, bands of asbestos 3 to 6 inches wide and 10 to 100 feet long occur in the great magnetic iron ore mine at Cornwall, Lebanon County. Although the quantity of asbestos in this mine is greater perhaps than known at any other locality in the State at present, it is not deemed sufficient for commercial utilization.

Easton. On the bank of Delaware River 2 miles north of Easton, Northampton County, in a talc and serpentine quarry operated by C. K. Williams & Co., pale green fibrous serpentine occurs and occasionally soft, silky chrysotile in fibers a foot long may be found. The chrysotile is the slip-fiber variety.

Lafayette. Old reports record amphibole asbestos in Rose's quarry, opposite Lafayette, Montgomery County. This may be the old soapstone quarry in Lower Merion Township, on the west bank of Schuylkill River, 2¾ miles below the bridge at Conshohocken. Mr. Wanamaker who lives on the river bank at, and used to work in this quarry says that short lenses or bands of asbestos were found occasionally when the quarry was being worked many years ago. The longest fibres were about 1½ inch, but there was no quantity. I found none in my examination of the quarry.

BARITE

Barite is a sulphate of barium, which when finely ground is used as an ingredient in certain paints, especially in place of white lead. It is called heavy-spar, from its high specific gravity, and also barytes, a word which is pronounced variously. Barite has a vitreous luster, white streak, is easily scratched with a knife, and resembles calcite but is nearly twice as heavy.

Geologically, barite occurs in veins or masses in limestone, as nodules in clay, and as gangue for metallic minerals.

FRANKLIN COUNTY

Barite as found in Franklin County is a white massive to crystalline mineral discoverable mostly as lumps the size of one's fist in clay residual from limestone.

The known occurrences are in the vicinity of Waynesboro and Chambersburg. According to Stose[3] the region is extensively folded and also exhibits major faults. The rocks concerned are Cambrian limestones and sandstones. Sandstones, schists and quartzites form the end of South Mountain, the encircling valley is underlain by limestone, and the Waynesboro formation, consisting of sandstone, hard purple sandy shale, and limestone forms a ridge which flanks the mountain face at a distance of 1 to 2 miles.

Stose says that in the vicinity of Waynesboro there are local pitching folds and that barite was deposited in brecciated portions of the limestone and sandstone on these folds, due probably to local segregation of disseminated barite from the adjacent limestone. When he studied the area bedrock was exposed in two openings. "Here the barite is chiefly massive, banded, suberystalline or granular, and milky, resembling chert, but is in part clear and crystalline. It occurs as a vein filling in the brecciated limestone. Such deposits are not profitable, as the ore must be crushed and separated from the rock; consequently they have been but little developed."

The barite prospects shown by Stose on the geologic map[4] of the Chambersburg quadrangle are in the Tomstown limestone, Waynesboro formation, Elbrook limestone, and Stones River limestone.

The chemical character of this mineral is shown by an analysis made by the Second Survey.[5]

> A sample of the Heavy Spar from Franklin County near Waynesboro, which was sent to the laboratory of the Survey by Mr. Burgess, was analyzed by M. D. McCreath with the following results:

[3] Stose, G. W., Barite in Southern Pennsylvania: U. S. G. S. Bull. 225, p. 515-16, 1904.

[4] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg (No. 170), 1909.

[5] Fraser, Persifor, Jr., The Geology of Lancaster County: Penna. Second Geol. Survey, Report CCC, p. 262, 1880.

Barium Sulphate ($BaSO_4$)	98.650
Strontium Sulphate ($SrSO_4$)	...
Alumina and Iron Sesqui-oxide (Al_2O_3 & Fe_2O_3)	0.140
Lime (CaO)	...
Magnesia (MgO)	trace
Silica (SiO_2)	1.110
Water (H_2O)	0.200
Sum	100.100

OCCURRENCE

The following information concerning the localities noted by Stose was obtained in August 1934.

Roadside. On the Doc. Bonebrake farm half a mile east of Roadside and just beyond a golf course in a cultivated field mapped by Stose as underlain by the Elbrook formation, a few lumps of barite weighing one to three pounds were found. All were on the higher part of the field. It is reported that barite was collected many years ago in some quantity from gullies in this field, and that about 1925 a small trench was dug in an effort to find a vein. A 4-inch vein was found in blue limestone but it pinched out 2 to 3 feet below the surface. Since then the field has been cultivated and no trace remains of the pit, which was near the highest corner of the field. Float quartz occurs here sparingly.

Tomstown. On the Earl H. Riley farm 1 mile southeast of Tomstown two shafts are reported to have been sunk about 50 years ago in a field about 150 yards south of the farm house. Mr. Riley says his father hauled barite from the farm to Quincy for shipment to a paint manufacturer. No trace of the shafts or pits remains nor could anything be learned of the occurrence of the ore. Small lumps of barite float can be found in the field, which, according to Stose, is underlain by Tomstown limestone.

On the top of a hill 1½ miles south of Tomstown on the Snoberger farm where Stose shows a prospect in the Waynesboro formation, there is a pile of sandstone float gathered from the surrounding cultivated field. Mr. I. S. Snoberger says his father dug barite from a pit at this spot about 50 years ago, but as he was only about 10 years old at that time he has no knowledge of the occurrence of the ore. At two points down the hill bedrock may once have been exposed as Stose says, but at both of these places any outcrop is now concealed by float stone gathered from the field. Barite was not seen on this farm.

Montalto. One mile southwest of Montalto on the farm owned by Roy Benchoff, formerly by Solomon Stamey, more prospecting has been done for barite, according to available information, than on any other farm in Franklin County. The site of former working is three-eighths of a mile west of the railroad at Knepper on the crest

of a ridge 150 feet above the creek. The ridge, according to Stose, is underlain by the Waynesboro formation, and two deposits were found here, one a vein, the other an associated residuum deposit.

John Wile, of Montalto, who worked on the Stamey farm for many years, says that Col. Weistling, superintendent of Montalto Furnace, began development here about 51 or 52 years ago (1882-3) and made an open pit on a N.30°E. course. Wagons entered at one end, were loaded, and driven out the other end. Mr. Wile is not familiar with the occurrence of the ore but says lots of barite was washed in troughs in the creek by turning it with forks or shovels, and shipped to Philadelphia "to adulterate white lead."

The open pit is now about 200 feet long, 20 to 30 feet wide, and up to 10 feet deep, having been partly filled by soil wash. Trees 6 inches in diameter are growing in the bottom of the pit.

About 1900-01 Col. Henry C. Demming of Harrisburg undertook to discover a body of ore by sinking a shaft in the north end of the old open pit. This shaft, according to Wile, was 65 feet deep, in limestone, with here and there a chunk of ore. Wile also related that Col. Demming dug a trench 15 feet deep, 10 wide, and 30 feet long in the field below the shaft but found only scattered lumps of barite. Wile thinks the site of the ditch was not well chosen for locating a vein of barite as there was another spot where his plow scraped across what might be the capping of a vein.

Wile says he loaded four railroad cars with barite at this time and the last of it sold for about $7.00 a ton f.o.b.

No trace remains of the prospect trench, and the shaft is completely filled and overgrown with brush and briars. Barite can be found, however, in the soil close to the shaft. These lumps are the size of two fists and smaller, and may have been dropped in loading the wagons. Mr. Wile says lumps the size of a human head, and even as big as a wash tub were found. Some of the large lumps contain angular cavities, which suggest that the barite was vein filling in brecciated limestone, and the angular fragments have been dissolved out.

The location of the prospect symbol on Stose's map is too close to the railroad and too low, the shaft and open cut actually being only a few feet below the crest of the spur ridge west of Benchoff's house.

Guilford Springs. On the old Lindsay farm ¾ mile north of Guilford Springs and 2 miles south of the Court House at Chambersburg barite is known to occur and was referred to by Stose in his folio. He maps the area as underlain by the Stones River limestone.

This farm is now owned by the Pennsylvania Railroad and occupied by a tenant farmer. No evidence of former prospect pits was found nor does Stose mention any. A small outcrop of limestone at the edge of the orchard shows two barite veins, one and two inches wide.

Occasional lumps of barite up to the size of a baseball can be found in the sod and along a stone fence near the house.

FULTON COUNTY

In 1882, J. J. Stevenson wrote in his report on the geology of Fulton County.[6] "Sulphate of baryta occurs in the Lower Helderberg on Dyson Fraker's farm near the creek, where it was mined somewhat extensively for a year or more. But the mineral, which was used exclusively in the adulteration of white lead paints, contains some iron, which rendered it worthless; the work was abandoned more than a year ago."

This locality is near Fort Littleton. Barite was found on farms half a mile northeast and one mile north of the hamlet as hydrometamorphic veins and as residual masses in the soil.

BUCKS COUNTY

According to Eyerman,[7] "Barite was formerly mined near Buckmanville, Upper Makefield, Bucks County, and the product sent to Easton, for use as an adulterant in the manufacture of paint."

This locality is in woods on the farm of Dr. Russell Richardson of Newtown, a few rods east of the road from Richboro to New Hope and $\frac{3}{4}$ mile SE. from Buckmanville. The largest excavation opened here for barite is a pit about 30 by 40 feet across and 20 feet deep. It has been used for the disposal of automobile bodies and other rubbish and bedrock is no longer exposed. Several small prospect pits are near. Massive barite can be found in the soil and forest litter around the pits and in the roots of an overturned tree.

More barite is readily found here than at the Franklin County localities. The nature and relation of the deposit was not determinable by the writer because there are no exposures. The following statement is quoted from the Trenton folio.[8]

> In the old baryta pit southwest of Buckmanville a breccia occurs, consisting of fragments of decomposed diabase in a matrix of quartz and baryta similar to the breccia north of Glenmoore (N. J.). No structural relations are exposed, but apparently the location is on the line of the Hopewell fault. It is possibly connected with an igneous intrusion which lies beneath the surface.

Should the price of barite increase materially, it might be justifiable to reexamine and prospect this deposit. It seems not to be recorded whether it was worked out. The occurrence in a breccia, however, makes it unprofitable to separate.

Barite occurs also near Logan Spring, Solebury Township, Bucks County. A sample collected by Dr. B. F. Fackenthal, Jr., Riegels-

[6] Stevenson, J. J., The Geology of Bedford and Fulton Counties: Pennsylvania Second Geological Survey, Report T2, p. 304, 1882.

[7] Eyerman, John. The Mineralogy of Pennsylvania, Part II, p. 20, Easton, Pa., 1911.

[8] Bascom, Darton et al., U. S. Geol. Atlas, Trenton Folio (No. 167), pp. 9, 21, 1909.

ville, Pa., and analyzed by Walter Wyckoff, chief chemist, Thomas Iron Company, had the following composition:

SiO_2	17.23	Al_2O_3	0.57	MgO	0.15
BaO	52.07	Fe_2O_3	0.45	P_2O_5	0.09
SO_3	27.17	CaO	0.36	Mn	0.00
					98.09

This analysis was furnished by E. R. Barnsley of Newtown.

Eyerman in his Mineralogy of Pennsylvania refers also to the massive variety of barite occurring at the Hinter quarry, Plymouth Township, Montgomery County, but gives no hint of the quantity.

CONCLUSION

At none of the localities mentioned did the writer find evidence to warrant the conclusion that barite occurs in quantity sufficient to justify prospecting with the hope of discovering the ore in commercial quantity.

CORUNDUM

The aluminum oxide, corundum, occurs usually in association with the serpentine that extends in isolated patches across Chester, Delaware, and Montgomery counties. The crystals are six-sided, commonly gray, and in some localities distinctly barrel-shaped. Corundum also occurs massive. Its color is blue-yellow, red, brown, or gray. Although corundum has been found at several localities, at only three places has it been mined. These localities are near Unionville, Chester County, Media, Delaware County, and Shimerville, Lehigh County.

Unionville. About 1½ miles northeast of Unionville in Newlin Township, Chester County, there is an area of serpentine about 1 mile long and 800 feet broad. Here there was discovered a century ago, large masses of brownish-gray granular corundum up to several tons in weight. Some of these were so difficult to drill into or break up that holes were dug beside them and they were buried deep enough not to interfere with cultivation of the soil.[1] In 1839 six or seven tons of loose crystals were shipped to Liverpool, England, and in 1848 a mass of corundum which weighed more than 5200 pounds was sent to the same place.

In 1866 about 5 tons of corundum dug here were sold for $60 a ton and in 1872 a mass weighing about 200 tons was discovered. Perhaps this is the same mass reported as found in 1875 and consisting of a lenticular body 5 to 10 feet wide and uncovered for a length of 30 feet and to a depth of 15 feet. This mass consisted mostly of corundum and margarite (calcium-aluminum silicate), but also included fine specimens of diaspore (an aluminum hydroxide).

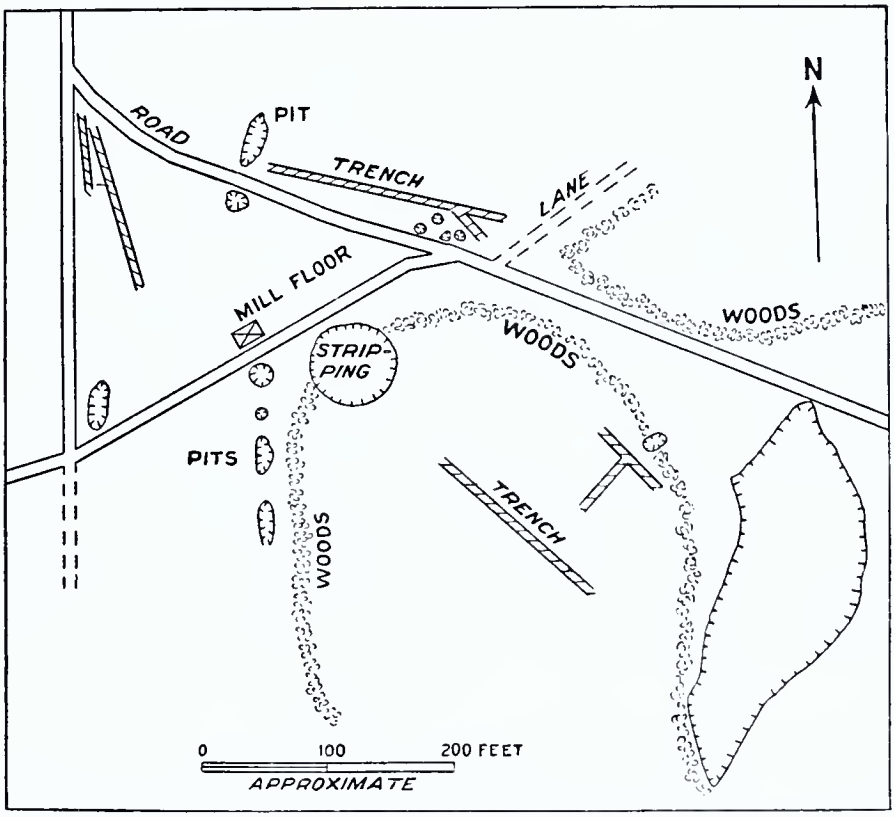
Corundum mined at this locality was hauled to Kennett Square, 5 miles south, where it was prepared in different sizes for the abrasives industry. Mining was done in a small way until 1882, but probably ceased about that time.

The writer visited this locality August 30, 1934 and found that the land is now owned by W. Plunket Stewart of Philadelphia. The old mine workings and prospects are on top of a hill at a triangular crossing of country roads, and distributed approximately as shown by the accompanying map. Approaching from the east one sees first on the south side of the road an area about 100 feet wide and 300 feet long sunk below the general level as if by a stripping operation or gully washing. Here were found several lumps of heavy coarsely crystalline rock the size of a football and difficult to break. They consist of margarite and grayish-black prismatic tourmaline, determined by Prof. E. H. Watson, Bryn Mawr College. Yellow quartz crystals were found here also.

Just west of this area on the edge of the woods is a small pit and rock dump, and in the woods behind it a trench. On the north side of the road at the east road forks is a small excavation in serpentine

[1] Geology of Chester County: Pa. Second Geol. Survey, Report C4, p. 349, 1883.

made recently for road stone. Close to the fence corner is a hole about 3 feet in diameter formed evidently by caving of the roof of underground workings for there is exposed about 8 feet below the surface what appear to be rock tunnels. They are filled with water about 10 feet below the surface.



Map of excavations on Corundum Hill, Newlin Township, Chester County.

Inside the fence are several small shallow pits and a trench leading N.70°W. about 200 feet to a pit about 40 feet long and 10 feet deep. Across the road from this large pit is a small one.

On the north side of the left fork of the road which makes the south side of the triangle is a concrete platform said to be the floor of a former grinding mill although old reports say the ore was sized at Kennett Square. On the opposite side of this road and extending in a southerly direction for 50 yards or more is a series of four pits, the largest of which is about 30 feet long and may have been 10 or 15 feet deep. Also on the south side of this road is a depressed area about 25 yards in diameter which looks like a shallow stripping. In the adjacent woods there are other excavations, evidently prospect trenches.

From the north point of the triangle a minor trench parallels the road to the south and a larger one extends S.10°E. 50 yards or more. In the south angle is another open pit about 30 feet long that may have been 10 to 15 feet deep.

If there was a shaft on the property I did not recognize it. The pits, trenches, and waste dumps are overgrown, bedrock is exposed only in the road and road stone quarry, and there is little or no mineral to be collected.

Mr. Wm. S. Gray, Media, Route 2, says that a block or boulder of corundum found at this locality is reported to have yielded $50,000. He and another man took a lease for three months on this corundum locality some years after production ceased and found only a few stray pieces of ore.

It might be assumed from the amount of excavation done here 60 years ago that all the corundum that could be discovered by extensive prospecting has been removed. There is no present surface evidence to justify a hope that corundum in commercial quantity can be produced here again.

Black Horse. At a road crossing about 2 miles west of Media, Delaware County, on U. S. Route 1, is the Black Horse Hotel, from which the Black Horse corundum mine took its name. According to Mr. Wm. S. Gray, who lives near this road crossing, the mine was on the land of his father, Castor W. Gray, about 300 yards above the old Gray home, which is still standing and occupied, and 40 yards below the upper line fence inside the hedge on the west side of the road. This would be about 0.3 mile southeast of Black Horse hotel, in a cultivated field now owned by the Williamson Trade School.

Corundum was mined here 50 to 60 years ago for about 18 months. Two shafts, each 8 feet square, were sunk to a depth of about 30 feet, and one smaller shaft. The ore was not a regular vein but in irregular bodies not over 5 feet in diameter, and pinched out at the bottom of the shafts.

Mr. Gray says the ore was shipped to New York. He believes it occurred in decomposed albite.

No trace of these old pits remains, they having been filled and the area cultivated for many years.

Mr. Gray says a pit was dug for corundum between the Black Horse mine and Ridley Creek on the John Smith farm, now owned by Elwyn Training School, but not much ore was found and the pit has long been grown over with trees and brush.

Shimerville. At this locality in the southern end of Lehigh County, 2 miles southeast of Macungie, barrel-shaped crystals more than 6 inches in diameter were found loose in the soil. The larger six-sided corundum crystals measured 8 by 4½ inches. Several tons of corundum are reported to have been taken from this locality.

The writer visited the place in October 1934. The old workings are half a mile due north of Shimerville in cultivated fields 200 yards east of the new concrete road leading to Emaus. They consist of partly filled trenches, probably once continuous, extending from the crest of the ridge down slope about 250 feet. The trench originally may have been 4 to 10 feet wide and 10 to 20 feet deep at the lower end. A shaft was sunk about 30 feet east of the trench but is now completely filled. These workings are on the farm of L. A. Hunsicker; it was formerly the Foster farm. A trench on the lower slope was for drainage.

According to Orvil Kreider, a local resident, corundum was first discovered here by college students. The first development was sponsored by John D. Shreiber of Allentown, John L. Shreiber of Shimerville, and Dr. Appel of Old Zionville. The soil and loose disintegrated gneiss beneath it was dug with pick and shovel and the stones separated out by throwing against a plasterer's screen. Presumably the stones were then washed and the corundum sorted out by hand. The local blacksmith says this was in 1882-3. It was at this time the ore was shipped. For some reason not known to the writer this operation was short-lived. The ore may have been exhausted, proved unsatisfactory, or its production was unprofitable.

About 20 years later or around 1900 a Connecticut company dug the trench and a shallow shaft but found little ore.

Bedrock is not exposed close by but the stones in the soil suggest that the corundum may accompany pegmatite intruded in gneiss. Chips and lumps of corundum an inch in diameter are not hard to find at this spot, especially when the sun is shining. Light reflected from crystal or cleavage faces draws attention to the mineral. Barrel-shaped crystals are rare in comparison with the number of fragments or chips that can be found. The crystals are crude and rough, and partly coated with feldspar and minute black crystals of spinel. Mr. Kreider of Shimerville presented the Survey with a rough crystal about 2 inches in diameter.

Other localities. Corundum crystals are recorded as having been found also in Delaware County near Village Green, in Ashton Township, and at Mineral Hill just west of Media; in Chester County near Fremont, West Nottingham Township, and near West Chester. The localities seem to have been of mineralogic rather than commercial interest.

FELDSPAR

Feldspar is produced in the United States largely in Maine, New Hampshire, Connecticut, New York and North Carolina. It is used in the manufacture of pottery, enamel ware, enamel brick and electrical porcelain. Pennsylvania formerly was a small producer.

The ceramic industry consumes over 80 per cent of the feldspar that is marketed. "Spar" is a constituent part of both body and glaze in true porcelain, white ware, and vitrified sanitary ware, and constituent of the slip and glaze of the so-called porcelain sanitary ware and enamel brick.

For use in making pottery feldspar must be nearly free from any mineral that will not burn white; especially must it be free from iron-bearing minerals, as biotite, hornblende, tourmaline and garnet.

Enamels applied to metals are fused with feldspar. Many of our own modern gleaming white bathtubs and wash bowls are made of cast iron to which, while still hot, is applied an enamel containing much feldspar.

Feldspar may enter into the composition of plate, window, and bottle glass. Crushed spar is used in the form of granules on roofing material and in facing on cement blocks designed to resemble granite. Small quantities are used for poultry grit and for an abrasive in scouring soaps.

The common source of feldspar is pegmatites. Their occurrence in Pennsylvania, with rare exceptions, is limited to the area of crystalline rocks in Chester, Delaware, Montgomery, and Philadelphia Counties. Practically all production of feldspar in Pennsylvania was by simple open pit methods. The localities are unglaciated and the surface exposures deeply weathered. This permits excavation with pick and shovel. Hand-sorted ore may be shipped in bulk or it may be pulverized and sacked. The last feldspar grinding mill in Pennsylvania was burned in 1928, not rebuilt, and with it the spar industry in this State ceased.

More than 275,000 tons were marketed in the first 30 years of this century and brought the producers and grinders around $1,200,000.

Most of the quarries are in Chester County and the remaining few in Delaware County.

Chester County. Eleven quarries were operated in West Nottingham Township in the serpentine barrens between two and three miles southwest of Nottingham. The principal ones were the Sparvetta, Keystone, and Brandywine. The first two were about 300 feet long and 150 feet wide; the Sparvetta was reported to have a maximum depth of 80 feet. The Brandywine quarry was 200 feet long, 60 feet wide and 115 feet deep. All are filled with water. Operations ceased about 1908.

In London Grove and New Garden Townships, spar was dug near Avondale, Baker Station, Toughkennamon and Chatham, and in Newlin Township at two places near Embreeville.

A quarry and mill were long operated on the Meredith farm one mile north of Sadsburyville, and small pits on the Boyle and Thorne farms 1½ miles northwest of Coatesville made some output. There are two quarries of considerable size on the Walker farm one mile east of Mendenhall in Pennsbury Township.

Delaware County. The principal feldspar quarries are near Elam, Chester Heights, Boothwyn and Twin Oaks.

Development about 300 yards southwest of Elam covers about four acres. Two of the pits are about 200 feet in diameter. At Chester Heights the old quarry is half a mile southwest of the railroad station on land owned by Mrs. Charles Felger. The Bunting quarry on land owned by H. E. Greene, the Halsey quarry on the land of Dr. G. F. Baier, and pits on the Boudwin farm, all near Boothwyn, and near Twin Oaks were once productive but have been abandoned so long that they are now overgrown or partly filled with earth or water.

Further information on these deposits is contained in Feldspar in Pennsylvania, by R. W. Stone and H. H. Hughes: Penna. Topographic and Geologic Survey, Bulletin M 13, 1931. This illustrated 60-page report is out of print but can be seen in the larger libraries throughout the State.

Although most of the feldspar quarries have been idle for many years and none are known to be operating in 1938, it is believed that the deposits are not exhausted, that other pegmatite dikes will be discovered, and that when the price is attractive, production will be resumed.

GARNET

Garnet is a fairly common mineral in the metamorphic rocks of Chester, Delaware and Philadelphia counties. In these and in Bucks, Lehigh, and Montgomery counties more than 80 localities have been recorded where one variety of garnet alone has been found. At least six varieties of garnet occur in this area. These are grossularite, pyrope, almandite, spessartite, andradite and uvarovite, of which the red or brownish-red variety almandite is most common, and uvarovite rarest.

The principal use of garnet is as an abrasive, either gummed to paper or cloth, or made into wheels. Its efficiency as an abrasive is partly due to easy fracture which renews cutting edges. About 90 per cent of the garnet produced in this country is used for the manufacture of abrasive paper and cloth which have a higher cutting efficiency than sandpaper. Powdered garnet is used in grinding, especially for grinding plate glass. Garnet is used as jewel bearings in watches, and crystals of fine color are cut for gems.

Although garnet has been found at many places, one might conclude that most of them are merely places where the mineral has been recognized, perhaps a few small crystals seen. At some of the localities listed, the country rock is liberally sprinkled with red to brown crystals less than one-tenth inch in diameter. At other sites notable single crystals were discovered half a century or more ago. Many of the sites, including quarries, have been visited many times by mineral collectors and all readily seen desirable material has long since been removed; the quarries have not been worked for decades, the ground is overgrown or built upon; and there never was a commercial quantity of the mineral.

At only a few of the places listed has garnet been of more than mineralogic interest. In the annual volumes on Mineral Resources of the United States it is recorded that garnet of gem quality was obtained in Pennsylvania in 1917. Where, how much, and by whom was not published. The Tenth Census (1880) credited Pennsylvania with an output of 60 tons of garnet, valued at $1200. As most of the garnet found in the State is almandite, the iron-alumina garnet, it may be assumed this was the kind produced.

In 1880 Hall[1] wrote: "The garnetiferous schist is mined—a short distance south of Green's Creek and near the north township (Bethel) line west of Chelsea." Herman, Behr & Company were the operators. This must have been the source of the 60 tons.

At the same time Hall mentioned the occurrence in Concord Township, Delaware County, of massive manganese garnet, fine specimens of iron-alumina garnet, and an abundance of small garnets in the soil near Green Creek. There is no record of production from then to 1903. From 1904 to 1907 there seems to have been one or two producers. In 1907 production of ruby or rose-colored garnet

[1] Hall, C. E., Geology of Delaware County: Pennsylvania Second Geol. Survey, Report C5, Pt. I, pp. 80-81, 1885.

found in gneiss was reported from Chelsea. That seems to have been the last. In Mineral Resources 1908 the decline in production of garnet in the United States was explained as due to the invasion of the field by artificial abrasives, overproduction in 1907, and a declining market.

Later activity is recorded by Brown and Ehrenfeld[2] in the statement "At present (1912) garnet is quarried north of Chester for abrasive use; it has been quarried until recently at Chelsea, Delaware County." But Mineral Resources of United States for 1912-13-14 definitely states that the garnet mine or mines in Pennsylvania were idle. Which of the quarries north of Chester was reported as producing in 1912 has not been learned.

The only garnet mines near Chelsea that the writer has seen, and perhaps the only ones in the vicinity, are in Concord Township 1.8 miles west of Chelsea. The site is reached by going west from Chelsea 1 mile on Route 61 to a crossroad and then southwest half a mile to a bridge over a branch of Green Creek. One mine or quarry is on the northwest side of the road and when visited in 1929 was surrounded by a high wire fence with a padlocked gate. Red garnetiferous rock is exposed in the quarry face above water. This property was said to belong to a Mr. Weis, a lawyer in Chester. On the opposite side of the road is a smaller pit owned by H. C. Clayton, Boothwyn, who lives near it. Neither pit has been worked in many years. The weathered ore is rusty; fresh fracture shows a reddish rock composed mostly of minute rounded crystals of reddish garnet and quartz, somewhat banded or gneissoid. The one small specimen in hand is practically all garnet, with possibly a little quartz and films of mica. This, however, may not be representative of the deposit; it may be an especially rich piece. The country rock is gneiss.

Having been abandoned for about 20 years when seen by the writer, there was little opportunity to learn much about the deposit or its development. No information is on hand as to the quality or extent of the garnet-bearing rock.

The production of abrasive garnet in the United States increased from 2,500 tons in 1897 to 7,000 tons in 1907, fell off to 2,000 tons in 1908, rose to 9,000 tons in 1923, fell off steadily to 1,950 tons in 1932, and rose to 4,800 tons in 1937. The value for the country has risen, however, from an average of $30 to $35 per ton in the 1890s to nearly $80 in 1937.

In view of the increasing perfection and use of artificial abrasives manufactured from low-cost raw materials, it is questioned if there will ever again be commercial justification for attempting to work the Pennsylvania deposits.

[2] Brown, Amos P., and Ehrenfeld, Frederick, Minerals of Pennsylvania: Topo. & Geol. Survey Commission of Pennsylvania, Report 9, p. 66, 1913.

GRAPHITE

By B. L. Miller

Graphite, also known as plumbago and black lead, is a soft, steel-gray to black mineral, a more or less impure, native form of carbon. It is a very stable mineral under atmospheric conditions and flakes of it are always found in soil derived from graphite-bearing rocks.

Because its fusion point is very high, probably above 3000° C, one of the principal uses of graphite is in making crucibles and other refractory products for the steel, brass, bronze, and electrochemical industries. Other uses are in the manufacture of stove polish, foundry facings, lead pencils, paint for metallic surfaces, and lubricants.

The following table represents approximately the use of graphite in various manufactured products:

	Per cent
Lubricants	24
Crucibles	23
All other purposes	17
Foundry facings	10
Paint	10
Lead pencils and crayons	8
Electrodes, brushes, etc.	6
Stove polish	2

Graphite occurs naturally in igneous, metamorphic and sedimentary rocks and also is produced artificially.

That graphite is common is shown by the fact that it has been produced in the majority of States in the Union. In view of this wide distribution it is unfortunate that the United States is still unable to supply the demand and that the imports of this useful mineral continue to surpass the output. This is mainly due to the fact that no grade of graphite has thus far been found in the United States that possesses certain of the desirable qualities of the foreign graphites, especially for the manufacture of crucibles and lead pencils as well as the fact that some of the foreign graphites can be sold in our markets at lower prices than the domestic product, even in spite of the tariff.

The graphites of the United States belong to the two classes, amorphous and crystalline. Pennsylvania has produced crystalline graphite alone, but the mines have been idle for many years. Three States producing crystalline graphite in recent years are Texas, Alabama, and New Jersey, named in order of importance. At an earlier period New York led in production, followed by Pennsylvania.

History

Graphite seems to have been first mined in Pennsylvania near Trevose and near Langhorne, Bucks County, about the middle of the eighteenth century. In the 1850s graphite was produced near Pughtown, Chester County and Vera Cruz Station, Lehigh County. In the late '70s graphite was dug near Boyertown.

The graphite deposits in Pickering Creek Valley in Chester County are the most important ones in the State and were first worked in the late '70s. Production probably was small for many years. There is a recorded output of 2721 tons in 1889 and 50 tons in 1892. Output was sporadic, partly because of the occasional burning of mills. From 1909 to 1919 the industry was more or less active. Nearly 700 tons were produced in 1907 and over 900 tons in 1910 but in 1911-13 little was done. The year 1916 witnessed unusual activity and 548 tons were produced. During two years of our participation in the World War the output was 910 tons, but this fell off to 242 tons in 1919, and no production has been reported since 1920.

Geology

The graphite deposits of Pennsylvania are limited to the greatly metamorphosed pre-Cambrian rocks of the southeastern corner of the State. Graphite has been mined in Chester, Berks, Bucks and Lehigh counties. The most important districts lie in the valleys of Pickering and French creeks, Chester County. In Pickering Valley, graphite has been mined in many places between Kimberton and Byers, a distance of about 8 miles. Deposits in Berks County are of secondary importance. Extensive mining has been done near Boyertown, Longswamp and Mertztown. Bucks and Lehigh counties may have some deposits worthy of investigation.

The graphite of Pennsylvania occurs mainly in graphitic gneisses and schists. In some places graphite is rather evenly distributed through marble. In Pennsylvania no attempt has been made to separate graphite from this coarsely crystalline marble and probably never will be.

The most common occurrence of graphite in Pennsylvania is in gneisses. All the graphite mines of the State have been opened in a rock known as the Pickering gneiss. It is a metamorphosed pre-Cambrian sediment that is composed primarily of feldspars, quartz, biotite, hornblende, calcite, and much graphite. The rock is extremely variable both in mineralogical composition and in texture. Some layers consist almost entirely of feldspar and quartz; some layers or lenses contain much biotite and no graphite; and some both biotite and graphite.

The soils derived from the Pickering gneiss are almost invariably stained red by limonite and hematite, so that they are an indication of the underlying rock even where no outcrops occur. In the decomposition of the original rocks graphite is the only mineral present that seems to have remained unchanged, and bright flakes of it are common in the soil.

The graphitic gneiss readily decomposes and in most mines in the State is so thoroughly decayed, even at the lowest levels, that the crushing of the rock is an item of small expense.

The graphite of the Pickering gneiss occurs in three forms: (1) as an important constituent of the rock evenly disseminated in interlock-

ing grains with the other rock minerals, (2) in pegmatites, and (3) in small veins.

The evenly-disseminated graphite constitutes the bulk of the graphitic material of the Pickering gneiss and is the main source of supply. The richer graphite-bearing beds are in some places sharply separated from the barren beds but more frequently there is a gradual diminution in the amount of graphite in the underlying and overlying strata. It seems probable that rich and poor graphite-bearing beds in the form of more or less persistent lenses occur in many places throughout the Pickering gneiss.

The thickness of the beds rich enough to warrant working varies greatly in the different mines. In some places the workable beds are only 6 to 10 feet thick and two or more beds may be worked in the same mine; in other mines the total thickness of workable material has not been determined but is more than 100 feet.

The amount of graphite contained in the Pickering gneiss, according to different operators, ranges from 3 percent to 10 percent. It seems probable that the average graphite content of the rock worked was 3 to 5 percent, of which 80 percent was recovered.

The graphite flakes of the Pickering gneiss are thin, are arranged parallel to the foliation planes, and, in the main, range in diameter from 1/16 to ⅛ inch, with the average probably about the mean of the two.

The second method of occurrence of graphite of the Pickering gneiss is in the pegmatites, and there are few mines where the pegmatites have not yielded a considerable amount of the material. The pegmatites range in width from a few inches to 15 feet or more, have a considerably greater length and depth, and cut across or lie between laminae of gneiss. They are readily distinguished from the gneiss by their coarse grain.

Graphite in the pegmatites is in large flakes, many of them one inch or more in diameter. It may be evenly distributed or occur in bunches. Many of the pegmatites contain graphite only in the outer portions. Although the richest specimens of graphite can be obtained from the pegmatites, these bodies are of little economic importance. The average percentage of graphite is probably slightly less than in the surrounding rock and the graphite is of poorer quality.

The third way in which graphite occurs is in veins. These are not common and no veins thicker than ¾ inch have been observed. The graphite in the veins is practically pure and occurs as curved leaves at right angles to the walls, thus resembling the Ceylon graphite. These veins are so infrequent that they are of little economic importance.

Mining

Most of the graphite mining in the State has been done in open cuts, and as the ore outcrops pits can be opened at little expense. In most places the beds dip 30° to 50°, so that cuts 30 to 40 feet deep

can be made before it becomes necessary to remove any considerable amount of barren overburden. Rotten rock at the surface continues to this depth. Picks and shovels are the tools used. Steam shovels have been found to dig the rock successfully.

One underground mine encountered only decomposed ore in a shaft 143 feet deep. Another had a 60-foot slope and extensive drifts and stopes in soft rock. In most places, however, the ore and wall rock is so decomposed that considerable timbering must be done. It is necessary to pump water from the underground mines, but mining can be done regardless of the weather, which is not true of open pit mining.

The greatest problem confronting the producers of graphite is the economical and efficient separation of the graphite from its associated gangue minerals. That, however, is a technologic subject outside the province of this paper. Suffice it to say that the problems are numerous and difficult but have been solved in many sections.

Use

During the World War, more Pennsylvania graphite was used in the manufacture of crucibles than for any other single purpose. Next in importance was its use in the manufacture of lubricants. The very fine graphite flakes and dust were used for stove polish and foundry facing.

Outlook for Future

Graphite mining in Pennsylvania has been a precarious industry. The curse of the graphite industry has been the promoters' schemes, and the cupidity of the owners of the mines or their failure to appreciate the difficulties attending the concentration of the graphite. The instability of the operating companies prevented a fair trial of the district. Cleaning and concentration of the flake has been the greatest difficulty. Many of the mines were over capitalized.

There is no scarcity of rock that will carry 3 to 4 per cent of good flake graphite and is reasonably free from mica and other objectionable minerals. The rock is mined easily from open pits, there is little or no overburden to be removed, much of the graphite is in rotten rock, and the fresh rock presents no crushing problem. Water is readily obtainable. In other words, the natural difficulties in the way of profitable production are not of such a character as to discourage operation.

What is needed far more than anything else is conservatism and stability on the part of the producer. Particularly are experienced men needed for milling the ore, men with imagination and ingenuity to experiment until a successful means of concentrating the graphite has been worked out and proved.

Finally the market for graphite should be carefully considered. The field for Pennsylvania graphite is restricted by prejudice or preference for foreign graphite. Artificial graphite is a strong competitor for certain uses.

Moderate capitalization, conservative expenditures, stable financial management, and experienced superintendence may some time yield satisfactory returns in the graphite industry in Pennsylvania although the present outlook is not promising. It has cost several dollars to produce every dollar's worth of graphite that the State has yielded.

MAGNESITE

Magnesite is a white mineral occurring usually in veins and consisting mostly of magnesium carbonate. Its principal use is for lining open-hearth steel furnaces and in normal times the steel plants in Pennsylvania consume many thousands of tons annually The second largest use is in oxychloride cement which is employed widely for sanitary flooring. Magnesite is used also as wall plaster, for making artificial marble, tile, sinks, fireproof and damp-proof paints, heat insulation, and the light metal, magnesium. To prepare it for any of these uses magnesite is first burned, which drives off the carbon dioxide gas that constitutes one-half of its weight.

Previous to 1914 practically all the magnesite used in the United States was imported from Greece and Austria but during the war, deposits in California and Washington supplied the country's need, which is very largely as a refractory lining for furnaces at steel plants. The principal market for magnesite therefore is between Chicago and the Atlantic Coast. As the only developed domestic source is on the Pacific Coast, the cost is high.

The demand for magnesite on the Atlantic seaboard and the high cost of the material resulted in the summer of 1921 in an investigation of the possibility of working the Pennsylvania deposits profitably. The magnesite deposits in Pennsylvania are in Chester and Lancaster Counties near the oxbow of Octoraro Creek on the Pennsylvania-Maryland State line. According to F. A. Genth in his preliminary report on the Mineralogy of Pennsylvania published in 1875, the magnesite deposits were first opened in 1835 and for the next 5 years about 150 tons per annum were shipped to Messrs. Handy and John Ellicott of Baltimore; between 1840 and 1850, on an average also about 150 tons a year, to Samuel and Philip Ellicott. The mines were idle for 4 years, then opened in 1854 and worked until 1871 by Powers and Weightman of Philadelphia, producing annually an average of 500 tons. According to Rogers in his report on the Geology of Pennsylvania published in 1858, "The excavation of this material is no longer pursued; it was dug only in superficial pits." The magnesite was used as a source of Epsom salts (magnesium sulphate) and other preparations of magnesia. Mining operations were discontinued when large masses of kieserite (magnesium sulphate) were discovered in rock salt mines at Stassfurt, Prussia, and magnesia products were imported at low cost.

It was these pits abandoned many years ago (1871) that were the scene of operations in the summer of 1921. The development work was done in the old workings in Chester County just east of Goat Hill which is five miles southwest of Oxford. The locality is within a few rods north of the State boundary in a hilly country unfit for cultivation and covered with scrub timber. The time elapsed since mining ceased is indicated by cedar trees 15 inches in diameter growing in the old pits. The reexcavated workings show that the magnesite occurs as a fine net or stockwork of small veins in the State line serpentine. Most of the veins are less than one inch wide. Two principal systems

of veins cross at right angles; the veins of the north-south system stand nearly vertical but those of the east-west system dip south at a high angle. In the reopened quarry two veins were disclosed, one about 14 inches wide and the other, which extends a few rods farther east into an open cut, about 12 inches wide. There seem to be few veins more than one inch wide except the two mentioned. A thorough exploration, including the reopening and drainage of a shaft with underground drifts, failed to disclose any larger veins, but it is reported that a body of magnesite about 30 inches wide was found in the shaft at the crossing of two main veins.

The development work done in 1921 showed that the quantity of magnesite available close to the surface is very small and that many tons of waste would have to be handled to produce one ton of ore. Production on a commercial scale was therefore not attempted. The magnesite is of the white amorphous kind, like that produced in California and Greece. It has the typical curved porcelaneous fracture and is apparently of high grade. Analyses have not been made by the Federal or State Survey because the small quantity of ore would not justify it. During the development work in 1921 a few tons of ore was extracted, but as taken from the quarry and pits it is mixed with serpentine and to prepare it for market would require breaking and careful sorting by hand. The small quantity of ore available would not justify the expense of cleaning.

Magnesite was mined also in Lancaster County about 90 years ago. The report of the Second Geological Survey of Pennsylvania on that county records the occurrence of the mineral in Fulton Township. It is reported that magnesite forming the gangue of the ore at the Wood chrome mine was obtained in considerable quantity and that a large quarry showing abundant magnesite was opened in the serpentine belt about three miles southeast of Peach Bottom. At these localities, however, it is not in commercial quantity. At several other places in the serpentine areas magnesite has been identified occuring in small stringers.

In view of the large quantity of magnesite used annually in Pennsylvania it might be regretted that large deposits of this mineral have not been discovered within the boundaries of the State. However, there is in Pennsylvania an abundance of dolomite or magnesian limestone which can be substituted for magnesite in some of its uses. Dolomite is now being dead-burned to make refractory lining for steel furnaces and has long been the source of magnesia for pipe covering and other heat insulation, for pharmaceutical purposes, face powders, toilet articles, and in the rubber trade.

PHOSPHATE MINERALS

Minerals bearing phosphoric acid or its compounds are numerous but few of them are of commercial value. Those occurring in Pennsylvania are

Amblygonite, a fluo-phosphate of aluminum and lithium.

Apatite, a lime phosphate with fluorine and chlorine, carrying 41-42 per cent phosphoric acid.

Pyromorphite, a lead phosphate, 10-18 per cent phosphoric acid.

Vivianite, a hydrous phosphate of iron.

Wavellite, a hydrous aluminum phosphate, having 19-35 per cent phosphoric acid.

Amblygonite has been recognized in association with wavellite near Reeds Gap, in Juniata County.

Apatite occurs as crystals and in massive form in many localities near Philadelphia, but nowhere in commercial quantity.

Pyromorphite has been identified with lead and zinc ores in Bucks, Chester and Montgomery Counties.

Vivianite occurred as colorless or greenish slender crystals at the Gap nickel mine, Lancaster County.

Wavellite is a colorless, white, yellow or green, vitreous to pearly mineral, in minute prismatic crystals, usualy in radiating aggregates or druses; hemispherical or globular aggregates with a radiating structure. This is the only phosphate mineral that has been mined in the State, and then only at two places many years ago with little success. One locality is at Moores Mill, 4 miles west of Mount Holly Springs, Cumberland County, and the other at Ross Farm Station, near East Waterford, Lack Township, Juniata County.

Cumberland County

The following is abstracted from a report by Geo. W. Stose:[1]

> Twenty miles southwest of Harrisburg and four miles west of Mount Holly Springs, a deposit of wavellite occurs in white clay associated with manganese and iron ores. For many years iron mining was a prosperous industry along the foot of South Mountain in this region, but the mines have long been idle. Associated with the iron, in general underlying it or on the side toward the mountain, is a body of clay used for wall paper filler and other purposes. In one of the prospect pits on this clay, on the property of T. J. Spangler near Moores Mill, peculiar round white nodules, chiefly in aggregates and botryoidal masses, were found in the white clay. The less weathered of the nodules when broken open show a beautiful radiate silky fibrous structure. This mineral proved to be wavellite. The American Phosphorus Company was organized by Philadelphia capitalists to develop the deposit, and a mill for the extraction of phosphorus from the ore was built near the mine in 1902. The mine was opened in 1900, and first years were devoted to prospecting and experimenting with the reduction of the ore. The

[1] Stose, Geo. W., Phosphorus Ore at Mt. Holly Springs, Pa.: U. S. Geol. Survey, Bull. 315, pp. 474-483, 1907.

mine was in active operation in 1905 and 400 tons of ore were reported to have been extracted and reduced in the company's furnaces. The mill was burned down and another was built and put into operation by 1905. Electric furnaces were installed in the new mill and operated during 1905, but the production of electricity by steam was too expensive, and in 1906 the mill moved to York Haven, where electricity generated by water power could be had. The output of the mill was phosphorus, used chiefly for making matches.

The mine was an open cut which, at a depth of about 30 feet, was stopped because of water. A shaft was said to have passed through clay with phosphate ore from a depth of 12 to 52 feet, at which point 16 feet of manganese ore was encountered. The phosphate ore was in lumps scattered through white clay. The deposit apparently was limited in width to 40 or 50 feet, with a depth ranging from a few feet on the valley side to 50 feet on the mountain side, and of undetermined length.

The wavellite and the manganese and iron ores are secondary deposits in surface deposits in part residual, in part transported, occurring near the contact of the Tomstown dolomite and Antietam sandstone of Cambrian age.

Stose wrote this description while the mine was in operation. I visited the place in 1922, was told that the brick mill on the railroad was little used after it was built; found the mine on the mountain side in the woods at the end of a lane half a mile long. The open pit was about 100 feet in diameter and caved or washed in so that the depth was only about 25 feet. Drifts seem to have been run at three levels in the sides of the pit. The conclusion was reached that operation ceased about 1906. Whether the ore gave out or was too scattered for profitable operation, or what may have been the reason for abandonment was not learned.

It is possible that wavellite occurs in the same geologic relation elsewhere along the north flank of South Mountain and in the valley of Mountain Creek south of Mount Holly Springs, but this has not been determined. Should the mineral be present, its occurrence may be so sporadic as to make exploration financially very hazardous.

Juniata County

Wavellite and amblygonite were reported[2] many years ago as occurring in the western end of Juniata County. According to Prof. M. C. Ihlseng of State College, these minerals occur at various points within 12 miles of Reeds Gap along a so-called black belt at the foot and on the flank of the low ridge formed by the Oriskany sandstone resting on the Lower Helderberg limestone. This belt is reputed fertile and its soil is strewn with nodules which are reported to contain as much as 30 per cent of phosphoric acid, equivalent, in commercial language, to 66 per cent of bone phosphate.

Prospecting has revealed concentration of phosphatic mineral in a heterogeneous mass of marls and sand derived from the contiguous formations. Two or three obscurely bedded layers or seams varying

[2] Ihlseng, M. C., A Phosphate Prospect in Pennsylvania: U. S. Geol. Survey 17th Ann. Rept., Pt. III, pp. 955-957, 1896.

in thickness and each containing a different type of rock appear to be conformable with the stratification of the enclosing rocks. Though there is a great diversity of pebbles, all containing more than 12 per cent phosphoric acid, they may be classified into three types: (1) a white, vesicular rock, soft, tasteless and dry; (2) red nodules resembling the concretions found within limestone; (3) blue limestone fragments, odoriferous on fracture and dense in texture.

Composition of phosphate rock

	P_2SO_4	Fe & Al	Insoluble
White rock	30-54	5-7	30-50
Red nodules	21	18	30
Blue rock	40	18	33

In addition to these three types, the entire mass of detritus between the Oriskany sandstone and the Onondaga limestone has been phosphatized to an extent varying from 3 to 12 per cent of phosphoric acid. There is a copious deposit of wavellite and amblygonite in the crevices and joints of the underlying flint.

Assuming a workable depth of continuous stratum for 100 feet, the yield of the seams in commercial rock will reach 15 tons per linear foot of outcrop. The dip of the beds is 40°. As the deposits are very accessible it would seem that if explorations prove the present isolated pockets to form portions of a continuous deposit, their nearness to consumers would give them a decided advantage over the higher grade southern product. If, moreover, other portions of the 1,100 miles of Oriskany outcrop in this State should be ascertained to contain similar pockets of phosphate, there is hope for the establishment of another important industry on this unique contact.

Notwithstanding the finding of phosphatic nodules and "calcareous pebbles" along this belt in many places, the writer believes that the prospect is favorable only in certain portions of the western end of the Oriskany outcrop in this State.

Thus Prof. Ihlseng described and discussed the situation 40 years ago. So far as known to the present Survey no further prospecting has been done or consideration given to these deposits. Presumably their development is not commercially feasible under present conditions.

The beds above described are on the west limb of a syncline. They rise to outcrop on the east limb along a straight line on the opposite side of Tuscarora and Lack Townships, paralleling Tuscarora Creek.

Many years ago, perhaps after Prof. Ihlseng's report was published, an attempt was made to mine phosphate ore in the vicinity of Ross Farm Station on the Tuscarora Valley Railroad near East Waterford in Lack Township. The locality is on the W. L. Newman farm. The Survey does not know the date, duration or success of the enterprise. Prof. B. L. Miller of Lehigh University visited the locality Sept. 3, 1931, in company with Dr. Bradford Willard of the Pennsylvania Geological Survey and Messrs. H. P. Dyson and J. W. Sheibley of Landisburg. Prof. Miller describes his findings as follows:

The workings consist of an adit driven into the side of a low ridge of Oriskany sandstone. The drift followed the strike of the rocks which is parallel to the valley. The drift is about 150 feet long and from it a number of cross drifts on either side extend 10 to 25 feet. At one point it appears that a certain band of the rock that evidently was richer in the phosphate minerals was followed downward along the dip of the strata, 40° to 45° N.W. The depth of this opening is not known.

The company apparently expected to mine a sizeable tonnage because a large mill and machine shop were erected. The foundations of the former remain and the shop is now used as a barn.

The drifts are in an extremely rotten impure sandstone that appears to be entirely or at least mainly Oriskany sandstone. Poorly preserved Oriskany fossils were seen in association with the ore.

The phosphate minerals are wavellite and possibly amblygonite. The minerals occur in small vugs and along enlarged joint planes in the rotten sandstone and in a yellow sandy clay. Some irregular, more or less hollow lumps in the clay are 6 inches or more in diameter. The thickest layers of solid phosphate mineral are along the bedding planes and range up to ¾ inch thick. All the phosphatic material is sporadic in distribution and apparently there is no definite layer of special concentration. The phosphatic material is glassy and greasy in appearance, possesses conchoidal fracture, and lacks the typical radiate structure of wavellite. In places the mineral is botryoidal or stalactitic. It varies from colorless to black or white. The black color is probably due to manganese dioxide, which was noted coating several surfaces.

The amount of phosphatic material disseminated through the rock must average very low. In places the sandy clay for considerable distance shows no ore whatever. Only a few extremely limited spots appear rich enough to be of any commercial value. It seems therefore that the deposit is of mineralogic interest only and has no economic value.

The conclusion reached by the Geological Survey from all the above data is that in the aggregate the two horizons mentioned may contain large quantities of phosphatic material but it is too disseminated and low grade to be of commercial interest at present.

POTASH

The chief sources of potash in Pennsylvania would be feldspar of the orthoclase and microcline variety, muscovite or white mica, igneous rocks such as rhyolites and granite, metamorphic rocks as gneiss and schists, cement-kiln fume, and flue dust of blast furnaces.

Feldspar was mined for many years in Pennsylvania and considerable quantities remain in Chester and Delaware counties, though production has ceased. The cost of extraction of potash from feldspar, however, is too high for feldspar to be considered a commercial source. When a cheap method of extraction is devised, the microcline that is no longer used for porcelain because of its iron content may become a source of potash.

Mica is nowhere sufficiently concentrated in this State to be mined and it too is not a commercial source of potash because of the high cost of extraction.

The granites and rhyolites of South Mountain have potash locked up in their mineral constituents but there seems little possibility of their use as a source of potash because of low percentage and difficulty of extraction. Likewise the mica schists and gneisses of the southeastern counties contain in the aggregate immense amounts of potash combined with silica and alumina but such sources will not be utilized until the more readily available potash in other combinations has been nearly exhausted.

The question may be asked whether the beds of rock salt and the brines encountered in deep wells contain potash in commercial quantity. From rather definite lines of evidence the assumption seems warranted that desiccation of the sea which formed the salt beds may not have reached the point where potassium salts would have been deposited. Furthermore the known beds of rock salt are more than 4500 feet below the surface in Bradford County and 6800 feet in Washington County. Analyses of brines from several deep wells show barely more than a trace of potassium.[1]

In the early part of the 19th century potash was leached from wood ashes. The lye so obtained was evaporated by boiling in an iron pot, whence the name potash, and the residue obtained, potassium carbonate, was much used in making soap. An occasional householder may obtain potash from wood ashes today, but it is not a commercial operation so far as known to the writer.

The only commercial production of potash in Pennsylvania during the present century has been from cement-kiln fumes and blast furnace flue dust.

By-product of Cement Industry

In the manufacture of portland cement in Pennsylvania the raw materials used are limestone, "cement rock," and shale. All of these contain a small percentage of potash, the proportion often exceeding

[1] Phalen, W. C., Salt Resources of the United States: U. S. Geol. Survey Bull. 669, p. 233, 1919.

1 per cent. In the ordinary processes of making cement clinker by crushing, properly proportioning and burning the ingredients, 50 to 75 per cent of the potassium is volatilized in the kiln and passes out with the flue dust. Any soluble salts are recovered by treatment with water, and the insoluble silicate combinations of potassium may be returned to the kiln to be revolatilized.

During the World War dust-collecting systems were installed at three or more cement mills in this State, and one portland cement company sold a large quantity of flue dust carrying about 6 per cent of soluble potash that had gathered under kiln stacks at the plant. Several methods were developed for recovering potash from cement-kiln fumes but with post-war return to normal prices the business became unprofitable and no potash was reported from this source in Pennsylvania after 1925.

In 1932, however, a new process of recovering potash from cement-kiln fume was introduced at a plant in Maryland. This process involves fractional precipitation of the flue dust by use of multiclones in series with an electrical precipitator. Should there be a resumption of production by improved methods the output of by-product potash from Pennsylvania might be very considerable in view of the large production of cement in this State. It has been variously estimated that, should all cement plants in the country recover the potash wasted in fumes, there would be a potential annual production of 50,000 to 100,000 tons of K_2O. As Pennsylvania produces one-quarter of the portland cement made in the country its plants alone might yield 10,000 to 25,000 tons annually.

However, in recent years the price of foreign potash delivered in this country has tended to curb American production.

By-product of Iron Industry

During the World War when potash from the usual foreign source was very high-priced or unavailable, every effort was made to develop a domestic supply. One source was blast-furnace dust. The Bethlehem Steel Company collected and sold blast-furnace dust for its content of potash in 1916 and probably was the first to do so. Two or three steel companies in Pennsylvania marketed this dust during the war and sales from this source continued for 10 years after the war. Probably the last sold was from the Lacy and Isabella furnaces of Carnegie Steel Co. in 1928, and the last outside the State was from a Virginia furnace in 1929.

Should the price of potash ever "sky rocket" again, the recovery of the enormous quantity of volatilized potash that goes to waste when a large number of iron furnaces are in blast, probably will be undertaken. The new source of potash from mines in New Mexico and Texas may, however, restrain any great rise in price.

All the raw material that is charged into an iron blast furnace—iron ore, coke and limestone—contains potash. Though the percentage is very small, the aggregate is large. Eighty per cent of this

potash is volatilized in the furnace and passes out with the gases, the remainder going into the slag. A small quantity of potash is retained in the dust-settling chambers, largely as fine particles of the original raw material. The washing of the hot gases by water apparently condenses and collects a considerable part of the potash they carry, and as this is in a large excess of water and not recovered, more than half that contained in the original furnace charge is lost. As the gases are consumed in the stoves and in the steam boilers their fuel value is utilized. In these a small part of the potash still held in the gases settles out, and this is a part of that which has thus far been commercially recovered. In quantity it represents only 0.3 pound of the original 22.4 pounds charged for each ton of pig-iron produced. About 2.6 pounds of potash is carried on farther by the gases and, passing into the open air, is finally lost.[2] The dust that settles in "stoves" and boiler tubes contains from 6 to 9 per cent water-soluble potash.

As about 2/3 of the potash in the original charge is lost, or about 15 pounds of potash per ton of pig-iron produced, there is a recovery problem here of some moment. At present, when no recovery of potash is attempted, all is lost.

No production figures are given because in recent years there has been no by-product recovery of potash, and during the later years of its recovery, production and sales by States and sources could not be given without disclosing individual output.

[2] U. S. Geol. Survey Mineral Resources, Pt. II, 1916, Potash, p. 137-8, 1919.

QUARTZ—FLINT

Although quartz is the commonest mineral in the rocks forming the earth's crust and occurs in a variety of forms, as crystals, irregular grains in igneous and metamorphic rocks, as veins, as rounded grains in sand and sandstone, that here considered is only one form, massive crystalline quartz (vein or pegmatite), or what is commonly known as flint.

Because it is much harder than steel, quartz is used as an abrasive; and for other qualities it is used in wood filler and paints, in artificial teeth, various kinds of pottery, china and sanitary ware, for fused silica apparatus, and for filtering strong mineral acids. Vein quartz must be crushed and pulverized for these purposes, and for some uses must be free of iron and other soluble mineral matter. In the massive form quartz is used for acid tower packing.

Quartz in one form or another occurs throughout the State, but vein quartz in anything like abundance or in quantity sufficient to be of commercial interest, seems to be found mostly east of Kittatinny or Blue Mountain.

Veins of quartz 5 to 10 feet wide occur in the Philadelphia area but mostly on private lands whose owners would not permit quarrying. Quartz is abundant in pegmatite in Chester and Delaware Counties, but so intimately mixed with feldspar, mica, and other minerals that its separation by hand cobbing or otherwise is commercially impracticable.

At Cornog on the East Branch of Brandywine Creek in Wallace Township, Chester County, vein quartz was dug about 1927 on the hill back of the home of Mr. Galt, just west of a large stone quarry. The vein is 12 to 15 feet wide, vertical, and of undetermined length, in the Chickies formation. According to Mr. Harry Rhodewalt, operator, the best material was sold for making sand paper and the rest went to steel works, presumably for use as a flux in smelting basic ores.

An iron-stained vein quartz occurring near Oxford, Chester County, has been used for building stone. The writer has not sought the source of the material.

The most conspicuous showings of vein quartz known to the writer are near Pine Grove Furnace and in Buchanan Valley in the South Mountain of Adams County. The occurrences will be mentioned in order from northeast to southwest.

Pine Grove Furnace. Crossing South Mountain from Cumberland Valley near Huntsdale, one sees large lumps of milky quartz along the road just south of the highest point and large blocks of conglomerate shot with many small veins of quartz. One mile down the road from the crest the distribution of quartz where the road crosses a spur suggests a vein 50 feet wide. The float quartz seems to trend in a SW. direction to the south side of a spur of Little Rocky Ridge half a mile north of Pine Grove Furnace at a locality known as White

Rocks. Here on the steep hillside several patches of quartz are exposed, the largest an area of approximately 50 by 150 feet. In the scrub oak on the gentle slope below the ridge there is a considerable quantity of quartz blocks. The largest seen is about 15 feet square and rises 3 to 6 feet above the soil. It was not determined whether this is float or in place; nor could the probable width of the vein be determined, because of lack of continuity of exposures in an area of dense brush. Tons and tons of vein quartz, freight car loads, strew the surface between White Rocks and the highway. In a continuation of the SW. course, quartz is abundant on Mountain Creek a mile up stream from the village. The country rock is ancient lava or aporhyolite.

Though much of this vein quartz is milky on the surface, when broken open it shows reddish or rusty stains on fresh fracture. If this mineral is pure enough to be serviceable, it has an advantage of only a half mile downhill haul to a railroad.

Wenksville. Two miles south of Pine Grove Furnace in a straight line but more than 4 miles by a travelable road, on the south side of Piney Mountain in Adams County are several old quartz quarries. This locality may also be described as 1¾ miles northeast of Wenksville on the Moses Black farm, now owned by Roy Adlesberger.

Back of the farm house on the far side of a large field is a small old pit now partly filled with field stone and grown up with trees and brush. Bedrock is not exposed here now, but about 150 yards to the west the right fork of a woods road leads to an open cut which exposes a quartz face about 15 feet high. Whether this cut followed a vein or found quartz only at the mine end was not determined because of the washed in and overgrown character of the excavation.

On the left fork of the woods road, probably on State Forest land, and may be 100 yards southwest of the cut just mentioned, is the largest quartz quarry in the whole South Mountain area, so far as known to the writer. This quarry runs into the side of a hill about 100 feet and has a face 20 feet high in which is exposed massive quartz, apparently in a vein lying at an angle of 20°. The ledge makes an outcrop about 50 feet wide. Although the weathered milky quartz is very white, iron staining is common, and streaks of soft green schist, locally called soapstone, that are mixed irregularly through the quartz would seem to make production of clean quartz difficult and the output of high grade quartz limited. Nevertheless a considerable quantity of "flint" has been taken from here, but not since 1920. It was hauled to a grinding mill at Aspers.

Quartz strewn on the surface and exposed in the road suggests a commercial quantity remaining, but probably not low in iron.

About 0.6 mile due north of the churches at Wenksville, on the Wm. A. Smith farm, on top of a ridge at a corner of the woods west of the farm house, a small quarry was once opened on a vein or "blow-out" of quartz. An area about 30 feet in diameter includes most of the quartz visible at this point. The small excavation exposes about

5 feet of one side of this body of quartz, but the pit may formerly have been somewhat deeper. The quartz weathers to a dull white, milky surface, but some is iron-stained and some has inclusions of green schistose rock.

Fragments of quartz are abundant in the cultivated field beside the quarry but decrease rapidly with distance. I did not see the evidence for a continuous vein here.

South of Wenksville on the road to The Narrows, one sees considerable quartz built into stone fences and also piled in heaps in cultivated fields. One heap contains enough to fill a coal car.

Buchanan Valley. Stose[1] has mapped a number of veins as continuous for several miles in Buchanan Valley, and the float from them is conspicuous in some places.

The largest quantity of quartz seen by the writer in the southern part of Buchanan Valley is along Route 234 about 1½ miles north of Lincoln Highway, at the house of Wm. F. Cole, whose address is Orrtanna, Route 2. West of the road 250 feet is a low ridge made by the outcrop of a quartz vein, but quartz float is very abundant in a belt 400 feet wide parallel to the road. Close to the road are two blocks of quartz 10 feet in diameter. Whether there is one very large vein here or several parallel ones is not known, but quartz certainly is abundant. Some of it is clearly milky but much is tinted light buff by iron stain. In fact tabular hematite occurs at one point in the quartz ridge on this property.

South Mountain, south of Caledonia Park. Quartz veins were worked years ago on the north slope of Huckleberry Hill, south of Caledonia Park, and the rock hauled to Black Gap for crushing. The largest quarry is 20 feet deep and 70 feet long. The presence of hematite in the quartz necessitated careful hand picking.

Vein quartz attracts attention around South Mountain Sanatorium and 3 miles east near Cold Springs, but does not seem to be abundant or in commercial quantity. It occurs on the E. J. Naugle farm on the east side of Green Ridge on the Cold Springs road and was used for building a chimney, in which the largest blocks are about 8 to 10 by 12 inches. This quartz, however, like that observed elsewhere in the neighborhood, is in part drusy, rusty, or contains rock inclusions.

Woodbine, York County. According to Second Survey report CCC, p. 182,

> A quartz vein is to be found about half a mile NE. of Woodbine Station, where a prominent ridge of white quartz 5 meters (5.4 yards) wide strikes north and south, and stands out boldly as a steep white comb of rock.

[1] Stose, G. W., Geology and Mineral Resources of Adams County, Pa.: Pennsylvania Topog. and Geol. Survey, C 1, 1932.
U. S. Geol. Survey Geologic Atlas, Fairfield-Gettysburg Folio (No. 225), 1929.

The writer visited this locality and found cultivated fields with an occasional block of quartz along fenee lines. Residents, however, direeted me to a prominent showing of quartz one-quarter mile SE. of Woodbine Station on the R. M. Ruff land. Large blocks of quartz are found in the woods from the road well up to the top of the hill. The largest exposures are high on the hill where two bloeks 12 by 15 and 15 by 20 feet rise 6 to 7 feet above the surface. The quartz is massive to much fractured, white, milky to translucent and erystalline. Although speeimens of very pure quartz can be obtained, so much of the rock is mottled and streaked with tan to violet iron stain that it seemingly would have no value for eeramies or other uses requiring freedom from impurities.

Iron-stained quartz was reported also in the ravine just northwest of the station.

ROCK SALT

Although seven to eight million tons of salt are produced annually in the United States and great stores of rock salt and brine lie beneath the surface of Pennsylvania, yet no salt is now produced in Pennsylvania. Neighboring States, New York, Ohio and Michigan are large producers of rock salt, and of natural and artificial brine, so Pennsylvania is under no necessity of mining salt at a high cost.

Salt licks and brine springs were discovered by the early settlers and for several decades in the nineteenth century salt was made along Conemaugh and Kiskiminetas Rivers and at other places in the western part of the State. Wells were drilled, mostly less than 1,000 feet deep, and an unfailing supply of salt water was obtained. Because the brine was weak, the reduction process took much time and fuel. At some places oil accompanied the brine and spoiled the salt. Up to about the time of the World War salt was evaporated from brine obtained from deep wells at two plants on Allegheny River near Pittsburgh, but eventually the brine became too weak for profitable extraction of sodium chloride.

Salt water occurs at varying depths in uncounted oil and gas wells in the western part of the State and may be considered as a reserve. Presumably this brine is too weak, in some places merely brackish, and cannot be reduced on a commercial scale to commercial salts at a profit; it may also be insufficient in quantity in some areas.

Rock salt has been recorded in at least 15 deep wells in 9 counties in the northern and western parts of the State. The occurrence of salt in these wells will be described by counties in the following order: Crawford, Elk, Erie, Forest, McKean, Potter, Tioga, Warren and Washington. Salt beds occur in the same geologic formation, the Salina group, which lies below the Oriskany sandstone and Helderberg and Tonoloway limestones in the upper part of the Silurian system and from which salt is derived in the neighboring States.

All the wells were drilled in a search for oil or gas in the Oriskany or deeper sands.

Crawford County

Three deep wells have discovered rock salt deep below the surface of Crawford County. The first of these wells, known as I. W. Whitney's Huidekoper No. 1, was drilled in a swamp south of Exposition Park and 2 miles NE. of Conneaut Lake village in 1916. At 3,200 feet, or 315 feet below the Oriskany sand 70 feet of white rock salt was penetrated, and the interval from 3,270 to 3,410 is recorded as lime and salt. The total depth of the well was 4,400 feet.

The James Naylor No. 1 well, 3 miles NE. of Conneaut Lake village, completed in 1923, went through several beds of salt.

Partial log of James Naylor No. 1 well, Vernon Township, Crawford County.

	Thickness	Feet Top	Feet Bottom
Sand, Oriskany		3023	3033
Lime, "Niagara"		3033	3314
Salt	10	3314	3324
Lime	8	3324	3332
Salt	43	3332	3375
Lime	115	3375	3490
Salt	50	3490	3540
Slate, lime and shale	135	3540	3675
Lime and salt	45	3675	3720
Salt	15	3720	3735
Lime	7	3735	3742

Here are more than 120 feet of salt, including two beds 43 and 50 feet thick.

The R. C. Jamison No. 1 well, 2 miles NW. of Jamestown in South Shenango Township, completed in 1930 at a depth of 4,619 feet, went through two notable beds of soft, white salt. After piercing a few feet of Oriskany sand at 3,100 feet and 300 feet of "lime," the drill found 75 feet of salt from 3,435 to 3,510, and 49 feet of salt from 3,621 to 3,670. From 3,680 to 3,720 is 40 feet of gray, shaly salt, and at two other horizons salt mixed with "lime" was recorded.

Elk County

The log of a very deep well in Elk County shows 10 beds of medium to coarse crystalline salt totaling 112 feet. The thickest single bed of salt measures 30 feet and occurs 6,015 feet below the surface.

This well is No. 3737 of the United Natural Gas Company, also called the Kane deep well, located 4 miles south of Kane, on Warrant 3788 in Highland Township. Drilling was completed in 1928 in the Queenston shale at a depth of 7,930 feet.

The sequence of beds at the salt horizons is shown in the following partial log:

*Partial log of Well No. 3737 of United Natural Gas Co., Elk County.**

Formation	Thickness	Feet Top	Feet Bottom
Limestone, Onondaga, Helderberg, Tonoloway, etc.		5318	5710
Shale, dark gray dolomitic	24	5710	5734
Salt, coarse crystalline	12	5734	5746
Shale, slightly calcareous	12	5746	5758
Salt, medium to coarse crystalline	12	5758	5770
Shale, dark gray	5	5770	5775
Salt, medium crystalline	13	5775	5788
Shale, slightly calcareous	6	5788	5794

* For complete log see Subsurface Silurian and Devonian sections across northern Pennsylvania and southern New York, by Charles R. Fettke, Bull. Geol. Soc. America, vol. 44, pp. 611-619, 1933.

Salt, medium crystalline	7	5794	5801
Limestone		5801	5903
Salt, medium crystalline	7	5903	5910
Limestone		5910	5994
Salt, medium to coarse crystalline	16	5994	6010
Limestone	5	6010	6015
Salt, coarse crystalline	30	6015	6045
Limestone	5	6045	6050
Salt, coarse crystalline	5	6050	6055
Limestone and shale		6055	6445
Salt, medium crystalline	5	6445	6450
Limestone and shale	30	6450	6480
Salt, medium crystalline	5	6480	6485
Clay, bottom of Camillus formation	5	6485	6490

Erie County

A well drilled in the city of Erie is reported to have reached the Trenton limestone, but the record on file with the Geological Survey does not mention salt. However, in the Wm. C. Kibler No. 1 well, about 1.7 miles southeast of Girard, which was completed in 1927, salt water was found at 1877 feet (5 bailers in 8 hours) and salt in the Salina formation from 2,298 to 2,369 feet, or 71 feet. Whether this is all solid salt or alternating beds of salt and shale or limestone is not specified.

A well on the Wm. Steadman farm near McLane, 5½ miles north of Edinboro, ended in the Queenston (Medina) shale at 3,735 feet. The log shows 15 feet of salt in the Salina group between 3,020 and 3,035 feet, or more than half a mile below the surface.

Forest County

The only deep well in Forest County in which salt is recorded is Collins and Richards No. 134 well on Cook oil lease, on Warrant 5236, 50 rods up Arner Branch of Bobs Creek, in Kingsley Township. This well was drilled in 1912. A partial log of well, covering salt in the Salina group, is as follows:

Partial log of Well 134, Cook oil lease, Kingsley Township, Forest County.

Formations	Thickness	Depth Top	Depth Bottom
Flint and hard limestone	325	4535	4860
Rock and salt mixed	5	4860	4865
Salt, white	40	4865	4905
Rock and salt mixed	5	4905	4910
Lava rock, hard	22	4910	4932
Sand, fine and hard	40	4932	4972
Lava rock	21	4972	4993
Salt	9	4993	5002
Limestone	15	5002	5017
Sand	36	5017	5053
Shells and salt	67	5053	5120
Salt and lava rock	30	5120	5150
Salt and shells	75	5150	5225
Lava rock	27	5225	5252

"Lava rock" in this usage is a tough sedimentary rock not readily identified by the driller, and "shells" means thin hard layers of tougher rock, perhaps sandstone or limestone. The 40 feet of white salt beginning at 4,865 feet is notable, and 172 feet of salt, shells and lava rock from 5,053 to 5,225 represents a lot of salt.

McKean County

The Derrick City well, drilled by the Bradford Deep Well Co., 4 miles northeast of Bradford, in McKean County, in 1912 and 1913 reached a depth of 5,820 feet. At 4,490 feet a 30-foot bed of salt was found, at 4,596 a 10-foot bed, at 4,638 a 47-foot bed, all salt, soft and white. Besides these 87 feet of salt in 3 beds, at 4,693 feet is the top of a 20-foot bed reported as salt and "lava." This group of salt beds lies below some limy beds. A log of this deep well is given in U.S.G.S. Bulletin 669, pp. 83-84, there called the Bradford deep well.

In the Potter Development Company's No. 1165 well, on the Zerbe farm 3½ miles west of Port Allegany, 22 feet of medium grained crystalline light gray salt was encountered at 5,073 feet in 1934.

Potter County

In Potter County rock salt was found in 1932 in the J. W. Matteson No. 1 well, which is about six miles southwest of Hebron Center, in the corner of Hebron Township. Under some dolomitic limestone below the Bertie water lime occurs 5 feet of medium-grained, crystalline, light gray salt at a depth of 5,528 feet and separated from a 10-foot bed of similar salt beneath by 7 feet of limestone.[1]

Susquehanna County

According to D. C. Harding, Susquehanna (letter dated Feb. 19, 1936) a well drilled in Steam Hollow 3 miles southwest of Halstead many years ago got salt water and natural gas 150 feet below the surface, and a well some miles away drilled under some secrecy encountered rock salt.

Tioga County

The greatest thickness of rock salt underlying Pennsylvania as yet disclosed by the drill was found under Tioga County in 1931. The J. E. Shoemaker No. 1 well of the Lycoming Natural Gas Corporation in Lawrence Township, Tioga County, was a dry hole at 7,148 feet, in that it yields no oil or gas, but the well-kept log[2] reveals valuable details of sequence and character of the rocks in the first 1-1/3 miles of the earth's crust at that point.

[1] Cathcart, S. H. Oil and Gas in Potter County, Pa.: Pennsylvania Topographic and Geologic Survey, Bull. 106, p. 13, 1934.

[2] Cathcart, S. H. and Myers, T. H., Gas in Tioga County, Pa.: Pennsylvania Topo. & Geol. Survey, Bull. 107, pp. 9-14, 1934.

Anhydrite, believed to be the top of the Salina group, was encountered 4,261 feet below the surface, and the first salt is recorded as "coarse, crystalline, grayish-white salt with a little interbedded light-gray shale 4,424-4,460 feet."

Between 4,424 and 6,508 feet depth the record shows 22 beds all or mostly salt, totaling 552 feet. Of these beds 16, adding up to 407 feet, are described as coarse salt with a little (or some) interbedded shale. They range from 6 to 55 feet thick. The remaining 6 beds are described as coarse, crystalline grayish-white salt. Two beds are each 6 feet thick, two are 7 feet, one is 25 feet, and the sixth is 94 feet thick. This last bed lies between 6,233 and 6,327 feet from the surface.

The suggestion has been made by S. H. Cathcart that this salt is on the crest of a fold and that the salt flowed under the pressure of folding, thickening on the crest and thinning on the flanks. It is likened to a saddle-reef deposit. Even so, supposing the original thickness of the beds is doubled by flowing, a bed of salt one-half the thickness of the great bed, or 47 feet, means a lot of salt.

The H. C. Kemp No. 1 well near Farmington Hill in the east end of Farmington Township passed through the Oriskany sand at 4,390 feet and found rock salt 800 feet below it at 5,200 feet, or just short of a mile below the surface. Salt continued to 5,270 feet and possibly to 5,375, the bottom of the well. Whether there is 70 or 175 feet of rock salt in the bottom of this well seems immaterial, in view of the depth and the quantity represented by the lesser thickness.

Warren County

Two wells in Warren County that were sunk to the Queenston shale penetrated rock salt. The first was completed at Youngsville by the Star Oil Company in 1922. The log shows 25 feet of salt in the Salina group. Only one bed of salt is recorded; it extends from 3,885 to 3,910 feet below the surface.[3]

In the Ulf No. 1 well, located a mile north of the borough of Tidioute and drilled in 1928, four beds of salt were found. Three are recorded as 5 feet of medium-grained, crystalline, light-gray salt. The fourth bed is recorded simply as 25 feet of salt between 4,930 and 4,955 feet below the surface.

All four beds of salt, totaling 40 feet, are between 4,755 and 4,995 feet depth. For a log of the well, see Fettke's paper cited above, under Elk County, pages 604-5.

Washington County

In Washington County a very deep well drilled by Peoples Natural Gas Co. on the R. A. Geary farm 4 miles northwest of McDonald is known as the McDonald well. It reached a depth of 7,214 feet in 1917. According to Phalen in U. S. Geological Survey bulletin 669,

[3] Johnson, M. E., Tidioute Oil Pool, Warren County, Pa.: Pennsylvania Topo. & Geol. Survey, Mim. Bull. No. 79, July 17, 1923, pp. 13-15.

salt water was encountered in this well at 6,825 feet and rock salt was found in the interval between 6,825 and 7,175, or approximately 350 feet.

A log of the R. A. Geary well in the Survey file shows, beneath 170 feet of limestone, an 8-foot bed of rock salt at 6,700 feet below the surface, 10-foot beds at 6,775 and 6,830, 5-foot beds at 6,860, 6,870 and 6,895, and a 20-foot bed of salt and lime shells at 7,020 feet. These beds of salt are separated by limestone. The aggregate is about 60 feet of salt in an interval of 340 feet.

The discrepancy of 125 feet in depth to the first salt bed is not understood but is rather immaterial at present, or so long as plans for recovering the salt are not under consideration.

Quantity of Salt

If the Salina formation underlies that part of the State west of the Allegheny Front and the northern tier of counties, then it underlies more than 20,000 square miles. We have evidence, however, of the presence of rock salt in only nine counties whose aggregate area is 8,013 square miles.

It has been shown above that wells pierced 71 feet of salt in Erie County, 87 feet in McKean County, 15 feet in Potter County, 145 feet in Tioga County and about 60 feet in Washington County. Just to illustrate the quantity of salt involved, we may figure as follows: One cubic foot of rock salt weighs about 136 pounds. One square mile equals 27,878,400 square feet. Therefore a layer of rock salt one foot thick over one square mile would weigh 1,895,731 short tons; a 10-foot bed would contain about 18,950,000 tons. A county like McKean having an area of 987 or Potter with 1,071 square miles, would have about 19 billion tons of salt under it in one 10-foot bed. If we multiply 18,950,000 short tons by 8,000 square miles in the nine counties known to be underlain by salt or by any greater thickness than 10 feet, we get a quantity of salt so great as to be inconceivable to the ordinary mind. The quantity of salt in a 10-foot bed under one county of 1,000 square miles would be equivalent to 2,700 times the quantity produced in the United States in a single year, or to a block of salt 1 mile square and 10,000 feet high.

In other words, one of the several counties in Pennsylvania underlain by rock salt could supply the world's demand for many years, were it necessary. In view of the depth of the salt below the surface, however, it is presumed it will not be commercially profitable to attempt to recover this material for many years to come.

Any estimate of quantity, of course, must be on the assumption that the drillers were correct in the identification of the salt and fairly accurate in the thickness. It is assumed that the mineral is halite, although, so far as has been learned, no analyses have been made of the material reported as salt from the deep-lying beds.

TITANIUM-RUTILE

The principal titanium-bearing mineral found in Pennsylvania is rutile, which is a titanium dioxide, TiO_2. Its color is red to reddish-brown, its luster metallic adamantine, and it ranges from transparent to opaque. Rutile occurs in needle-shaped or prismatic crystals, often twinned in geniculated or kneelike joints or bends. The prismatic crystals commonly are vertically striated and furrowed. The chemical composition is 60 per cent titanium and 40 per cent oxygen.

Rutile has been found in several townships in Chester and Delaware Counties, and it is reported from Lancaster and York Counties. These seem to be mostly occurrences of mineralogic interest only except the occurrence of loose crystals in the soil of Sadsbury Township, Chester County, especially near Parkesburg and Pomeroy.

Old reports state that the largest and finest crystals occur in quartz and loose in the soil in Sadsbury Township, Chester County, for 7 miles along the valley, especially near Parkesburg, where sometimes doubly geniculated crystals of one pound in weight have been found.

This area, according to the map in the Coatesville-West Chester folio (No. 223) of the Geologic Atlas of the United States is underlain by the Conestoga limestone of Ordovician age. This formation is described as thin-bedded limestone, with micaceous laminations and dark slaty partings. The exposures along the railroad half a mile or more west of Parkesburg look like mica schist standing nearly on edge. This rock contains small lenses of calcite in the cut on the low-grade line and fragments of quartz are common in the soil of adjacent fields south of the railroad.

The writer visited Parkesburg early in August, 1934, and learned from conversation, particularly with Mr. Alfred Clark, aged 87, that 50 or 60 years ago boys used to collect titanium (rutile) crystals in cultivated fields, particularly after a hard rain. The crystals occurred loose in the soil and were found mostly on the Parvin Smith farm on the west edge of town just south of the railroad. This farm is now part of the residential section of the borough. The crystals were bought mostly by Mr. Isaiah Matlack, but Ed More also was a buyer. The price paid was 35 to 50 cents an ounce. The buyers sold them to manufacturers of false teeth, some say for coloring the artificial teeth, others for an ingredient in the plate.

The crystals are reported to have been found only on the south side of the railroad and it is 40 or 50 years since any one has regularly searched for or bought the crystals. Mr. H. G. Cromleigh, hardware merchant, confirmed Mr. Clark's statement.

I searched for 1½ hours in the railroad cuts and in a cornfield paralleling the railroad on the south without discovering a crystal or fragment of rutile, though conditions were good for finding them if any are present. From this it may be concluded that the rutile crystals weather out of the limestone or calcareous schist and that all those occurring loose in the soil have long since been brought

to the surface by plowing and harrowing, and collected. Evidently the rutile crystals which once were fairly common can now be found only rarely if at all near Parkesburg.

At Pomeroy the writer was told by old residents that boys used to find titanium up to about 25 years ago and got 35 cents an ounce for it. The local wheelwright says it was found in the north bank of the railroad cut just east of the bridge over the railroad when the cut was widened to accommodate more tracks. None can be found there now however.

It is reported also that when the excavation was made for the basement of a public school in Pomeroy some laborers got as much money for the titanium found in the soil as their wages for digging. This story may be an exaggeration and the wages per man may have been small.

Mr. George McWilliams of Pomeroy, a track laborer on the Pennsylvania Railroad, says he has two pounds of good crystals found on his farm and that this mineral occurs along the Pennsylvania Railroad low grade from Christiana to Greentree in Lancaster County. Greentree is 9 miles west of Parkesburg and 11 miles from Pomeroy and on the same Conestoga limestone formation as the latter places.

This investigation results in the conclusion that the principal titanium mineral in this State, rutile, occurs in such small quantity in any one place as to be of no commercial interest.

VERMICULITE-JEFFERISITE

Character. Several micalike minerals that give off much water when heated, and in doing so expand greatly or exfoliate, are grouped under the general term, vermiculite. Several kinds that open out into long wormlike threads when heated gave the group name. One of the varieties that is found in Pennsylvania bears the name jefferisite, probably named for a mineral collector, Mr. Wm. M. Jefferis. J. D. Dana in his System of Mineralogy describes it as occurring "in broad crystals or crystalline plates. Surface of plates often triangularly marked by the crossing of lines at 60° and 120° angles. Cleavage: Basal, eminent. Flexible, almost brittle. H. = 1.5 G. = 2.30. Luster, pearly on cleavage surface. Color, dark yellowish brown and brownish-yellow; light yellow by transmitted light; also greenish yellow."

A vermiculite, probably jefferisite, was recognized by Prof. C. U. Shepard at Wood's chrome mine, Lancaster County, as early as 1866.

Occurrence. In a letter to the writer dated March 27, 1931, Samuel G. Gordon, mineralogist, The Academy of Natural Sciences, Philadelphia, says:

> Vermiculite, particularly jefferisite, occurs on the borders of pegmatite veins in serpentine areas. The deposits of this mineral are limited exclusively to such occurrences. The pegmatite veins intruding serpentine and its associated rocks are usually albitite, and owe their origin to the reaction which occurred between the pegmatite solutions and the serpentine. The reaction zone of pegmatites in serpentine consists of bands of vermiculite, talc, and actinolite; these bands being up to several inches in width.
>
> Vermiculite can be found in any of the old feldspar quarries in the serpentine areas of Delaware, Chester or Lancaster Counties. Anyone interested might advisably look over the serpentine areas for pegmatite veins and their borders of vermiculite.

Jefferisite was recorded by Genth[1] as occurring in veins in serpentine 3 miles south of West Chester (Brinton quarry); in hexagonal crystals 1 to 2 inches broad, near Unionville, Newlin Township, Chester County (Corundum Hill 1½ miles NE. of Unionville?); and a similar mineral in soapstone quarries near Lafayette, Montgomery County, and in small plates at Texas (Wood's chrome mine), Lancaster County.

Use. Vermiculite has been a commercial mineral little more than 10 years. Because when heated it assumes a golden or silvery luster it has various uses for decorative purposes; and its quality of expanding enormously, becoming so light that it floats readily, together with its low heat conductivity and resistance to high temperatures, make it suitable for sound deadening plasters and filler in walls, for insulation in safes, refrigerators, and boilers, for paint of bright gold or silvery color, and for wall paper and other decoration.

The jefferisite from near West Chester closely resembles the vermiculite mined in the Rainy Creek area near Libby, Montana.

[1] Genth, F. A., Mineralogy of Pennsylvania: Pennsylvania Second Geol. Survey, Report B, p. 129, 1875.

That material has been sold at Libby for $10 or less a ton for the crude vermiculite and $20 or more a ton for the heat-expanded product.[2]

Brinton quarry. Three miles south of West Chester in the south corner of Westtown Township and 1 mile west of Darlington Corners is the mineralogically well-known Brinton serpentine quarry. This quarry between 1862 and 1926 probably furnished more serpentine for building stone than any other serpentine quarry in the United States. Quarry operations were abandoned about 1926 and the hole filled with water has for several years been a country club swimming pool.

Among a variety of minerals found here, jefferisite, one of the vermiculite minerals, is conspicuous. A greater quantity has been found here than at any other place in the State, unless it be the Cornwall iron mine in Lebanon County. At Cornwall it has not been dug or produced, but at the Brinton quarry the mineral has been developed by a prospect trench and a considerable quantity, perhaps 250 cubic feet is stored in a shed on the property.

At the southwest corner of the quarry, there are two bands or veins of jefferisite from 2 to 5 inches wide, one running up the quarry face and one along it. This mineral is easily dug with a pick from between the walls of hard serpentine. At one place in the quarry it is in contact with fibrous serpentine.

Outside the quarry near its southwest corner a prospect perhaps 50 feet long, 4 or 5 feet deep, and wide enough for a tram track has been dug toward the quarry on a band of jefferisite. When visited in 1931 this cut was overgrown so that the dimensions of the mineral body and relation to country rock were concealed.

The land belongs to Dr. Christian Brinton, R.D. 5, West Chester. His father experimented some years ago with making wall plaster and cement shingles, mixing in or blowing on the soft plaster a small quantity of jefferisite for decorative effect.

Cornwall iron mine. According to W. O. Hickok, IV, of Harrisburg, vermiculite occurs among the silicate gangue minerals in the ore bodies at Cornwall. It is an alteration product of phlogopite and has retained the optical character and dark green color of the original phlogopite but has acquired the water of crystallization of vermiculite. It exfoliates readily on application of heat. It appears to be a weathering product of the phlogopite. Flakes half an inch in diameter are found scattered through the gangue and occasionally a lump of flakes the size of one's fist.

Geiger serpentine quarry. On the bank of Octoraro Creek just above the Maryland line in Fulton Township, Lancaster County, and 1½ miles south of Wrightsdale is the serpentine quarry owned by Walter Geiger, formerly operated by Octoraro Stone Co., Nottingham. In the quarry face, which is about 70 feet high, there was

[2] Pardee, J. T. and Larsen, E. S., Deposits of vermiculite near Libby, Montana: U. S. Geol. Survey, Bull. 805-B, p. 24, 1929.

exposed in 1934 a band of soft micaceous rock from 0-20 inches wide and continuous for several yards. This material appears to be mostly chlorite but contains small flakes of a brown mica-like mineral not over half an inch in diameter that is presumed to be jefferisite, for this mineral is reported from Wood's chrome mine in the same serpentine belt a mile east. Small flakes of this mineral heated in a glass test tube give off abundant water and swell or exfoliate very markedly. The calcined material has a golden-bronze color.

The bulk of soft greenish and bronze-colored chloritic mineral gives off water when heated and stirs in the tube due to the expansion of rare small flakes of jefferisite but otherwise is unaffected by heat.

The quantity of jefferisite in this quarry as seen in 1934 was very small and of mineralogic interest only.

Other occurrences. The writer has visited the Corundum Hill locality 1½ miles northeast of Unionville, Newlin Township, Chester County, also the Meredith and Boyle feldspar quarries near Coatesville and the Fazio feldspar quarry near Embreeville, and the Keystone and Sparvetta feldspar quarries near Sylmar, Chester County, and found no vermiculite. The waste dumps at Wood's chrome mine in southern Lancaster County have been worked over for crushed stone. In a recent visit vermiculite was not observed. The old soapstone quarry near Lafayette, Montgomery County, is so overgrown that there is no longer much chance of finding minerals here.

Vermiculite is reported also at a serpentine outcrop near Lenni, Delaware County, in the Second Geological Survey report on Delaware County, C 5, page 70, and at several feldspar quarries worked many years ago in that county.

MISCELLANEOUS MINERALS

Allanite

A complex variable silicate of aluminum, iron, the cerium metals, and in smaller quantity those of the yttrium group. An important source of rare metals, especially salts of cerium, which are used for the cerium-iron alloy that yields the sparks in a pocket lighter, and mixed with titanium oxide, its oxide gives a canary-yellow to glass.

Allanite is pitch-black, often coated with a brown weathering product. It occurs massive, as imbedded grains, and rough tabular crystals. It has sub-metallic, resinous, or pitchy luster, and is translucent to opaque.

This mineral has been found in the following localities: Berks County: Pricetown, and Trexler mica mine, Alsace Township; Chester County: Pughtown, Chester Springs, Comley Hall (east Bradford Township), Corundum Hill (Newlin Township), and Minorcus Hill; Delaware County: Lenni and Morton; Northampton County: Lehigh Mountain at Bethlehem, and Redington; and at certain

quarries in Philadelphia County perhaps now filled for building sites. These localities are underlain by granitic rock.

The Comley Hall and Lehigh Mountain localities are reported as bearing or having yielded "black masses" or "large black masses." Whether allanite can be found there now, and if so, in what quantity, can be answered only by field investigation.

Beryl

Beryl is a glucinium-aluminum silicate. It is used as a gem when clear and well-colored. It may be colorless, white, yellow, pale green, light blue, and occurs in hexagonal prisms and coarse columnar masses. Beryl occurs with pegmatites and mica schist particularly in Chester and Delaware Counties. This mineral may be in demand for its glucinium, also known as beryllium. The metal is sold in small ingots for use as alloy in copper, especially for copper springs.

Specimens of beryl have been found at many localities and of varying size up to a single crystal weighing 51 pounds from Beryl Hill near Unionville in Chester County. Crystals 10 to 12 inches in length and 1½ inches in diameter have been found in the micaceous schist at Leshong's quarry, near Leiperville, Delaware County, and good crystals at Avondale, Boothwyn, Mineral Hill, Trainer, and other localities in the same county.

None of the crystals are of sufficiently good color and transpareney to be gem grade, and the quantity so far as known is nowhere more than meager.

Cyanite

An aluminum silicate, generally in flat-bladed gray, grayish-black, blue, and bluish-green crystals. Sometimes used as a gem. Has been found principally in Chester, Delaware and Philadelphia Counties.

More than 50 years ago cyanite was found on Mt. Zion near Darby, and in blue, radiating bladed masses in granular quartz at White Horse, now Prospect Park, 3 miles below Darby. Gray, bladed crystals up to 3 inches long and 1 inch broad were found near Cope's Mill and Black Horse tavern just west of West Chester. Crystals were found one mile north of the corundum mine near Unionville, Newlin Township, Chester County; in quartz at Nevils Academy, near Bustleton, Bucks County; and in many other places in Chester, Delaware and Philadelphia Counties. Also reported from Collingdale, Delaware County.

So far as known to the Survey none of this material was of gem quality, and the occurrences may be of mineralogic interest only. However, good crystals of this mineral might find a market among mineral collectors.

Epidote

Epidote is a basic orthosilicate of calcium, aluminum, and iron, and occurs in columnar aggregates, granular masses, and prismatic crystals. The color is various shades and tints of green.

Flawless crystals of good color are used for gems. Rock composed largely of massive epidote occurs in South Mountain between Fairfield and Monterey but has no use unless it be for roofing granules or terrazzo floors.

Considerable massive epidote occurs also in metabasalt exposed by a road cut in the ravine at Accomac, York County.

This mineral is reported as having been found in Adams, Berks, Bucks, Chester, Delaware, Lancaster, Lehigh, Montgomery, Northampton and Philadelphia Counties, but so far as the records show it is not of gem quality.

Gems

The following minerals that, when clear and of good color, are used as gems or semi-precious stones, have been found in Pennsylvania. Amethyst, apatite, beryl, garnet, moonstone, opal, sunstone, tourmaline and vesuvianite. All the localities where these minerals occur are in the southeastern corner of the State. It does not seem to be recorded that material of gem quality has been found, but cut and polished specimens of some of these minerals from Pennsylvania localities are on display at the Academy of Natural Sciences, Philadelphia, and in other museums.

"Golden beryl has been found in good gem quality at the Avondale quarries near Swarthmore." (Penna. Topog. and Geol. Survey, Report 9, 1913, p. 19.)

Greenockite

This cadmium sulphide, which is described as honey to orange-yellow, adamantine to resinous amorphous coatings, usually found on sphalerite, is about 78 percent cadmium and 22 percent sulphur. Greenockite does not occur as a commercial deposit anywhere in the United States, but because of its presence on zinc ores, cadmium in commercial quantity is obtained as a by-product in smelting them at some places.

Greenockite was found as yellow, greenish-yellow or orange-coated earthy encrustations on ore in the Friedensville mines in Lehigh County. It is said to have been separated from the ore at the South Bethlehem furnaces, but this is doubtful. This mineral is reported also from the Perkiomen mine near Audubon, Montgomery County, and from York.

It is doubted if specimens of this mineral could be found at these localities now because the Friedensville mines have been abandoned for 40 years and the Perkiomen mine 70 years.

Tourmaline

As the only use of tourmaline, aside from cabinet or mineral specimens, is as a gem stone, especially the clear pink, blue, and green varieties, and as most of the references in the literature seem to be black, yellow and brown tourmaline, this mineral may be omitted from consideration.

Brecciated black crystals one inch in diameter and several inches long have been found in the Fazio feldspar quarry at Embreeville, Chester County; and small black needles of schorl occur in rocks at Valley Forge, in quartzite in the ridge north of Downingtown and other places.

Uranium-bearing Minerals

Uranium-bearing minerals found in Pennsylvania include autunite, carnotite, fergusonite, samarskite, torbernite, uraninite, and uranophane. So far as is disclosed by the references to these minerals, the occurrences may be mere minute crystals or small quantities sufficient for identification, and probably in no case of more than mineralogic interest.

MINERAL RESOURCES REPORTS

Discussion of other mineral resources will be found in the following bulletins of the Pennsylvania Geological Survey. These reports are on file in many public libraries throughout the State. Those not out of print can be bought from Division of Documents, Department of Property & Supplies, Harrisburg, Pa.

M 1. Oil and Gas Fields of Pennsylvania, Vol. 1, Introduction, by George H. Ashley and J. French Robinson. 1922. 79 pp., 4 pls., 9 figs., 1 color map. A condensed, introductory description of the origin, mode of occurrence, and conditions of development of oil and gas, with a brief description of each of the oil and gas fields of the State; also a small scale reconnaissance map of the oil and gas fields. Out of print.

M 2. Oil Resources in Coals and Carbonaceous Shales of Pennsylvania, by Chas. R. Fettke. 1923. 119 pp., 6 pls., 16 figs. Describes the petroleum situation, explaining methods of distilling coal and shale, and gives results of tests on 122 samples of coal and shale. Out of print.

M 3. Silica Refractories of Pennsylvania, by E. S. Moore and T. G. Taylor. 1924. 100 pp., 16 pls., 10 figs. Describes the character, distribution, and quarrying of ganister and mica schist, and the properties, manufacture, and uses of silica brick. Out of print.

M 5. Lead and Zinc Ores of Pennsylvania, by B. L. Miller. 1924. 91 pp., 5 pls., 7 figs. A description of the distribution, geologic occurrence, and origin of the ores, and a history of mining operations. Out of print.

M 6. Bituminous Coal Fields of Pennsylvania.

Part. I. General Information on Coal, by George H. Ashley. 1928. 241 pp., 17 pls., 32 figs. 50 cents.

II. Detailed Description of Coal Fields, by J. D. Sisler. 1932. 511 pp., 14 pls., including 5 color maps, 152 figs. The description is by counties. 50 cents.

III. Bituminous Coal Resources, by John F. Reese and James D. Sisler. 1928. 153 pp., 4 pls. 25 cents.

IV. Analyses of Bituminous Coal. 1925. 268 pp., 1 pl. By the U. S. Bureau of Mines. 50 cents.

M 8. Anthracite Losses and Reserves in Pennsylvania, by Dever C. Ashmead. 1926. 71 pp., 1 pl., 13 figs. Out of print.

M 10. Fire Clays of Pennsylvania, by J. B. Shaw. 1928. 69 pp., 6 figs. 25 cents.

M 11. Molding Sands of Pennsylvania, by R. W. Stone and American Foundrymen's Association. 1928. 94 pp., 21 pls., 10 figs. 25 cents.

M 12. Anthracite Culm and Silt, by James D. Sisler, Thomas Frazer and Dever C. Ashmead. 1928. 259 pp., 34 pls., 24 figs. 50 cents.

M 13. Feldspar in Pennsylvania, by R. W. Stone and H. Herbert Hughes. 1931. 60 pp., 20 pls., 6 figs. Out of print.

M 14. Magnetite Deposits of French Creek, Pennsylvania, by Laurence L. Smith. 1931. 52 pp., 5 pls., 5 figs. Describes the French Creek magnetite mine at Saint Peters, Chester County. Out of print.

M 15. Building Stones of Pennsylvania, by Ralph W. Stone. 1932. 316 pp., 4 pls., 164 figs. $1.25. This report calls attention to the different kinds of building stone available and illustrates their uses.

M 16. Slate in Pennsylvania, by Charles H. Behre, Jr. 1933. 400 pp., 5 colored geologic maps, 65 other pls., 89 figs. $2.75.

M 17. Clay and Shale Resources of Southwestern Pennsylvania, by Henry Leighton. 1933. 190 pp., 1 colored geologic map, 16 figs. 75 cents.

M 19. Contributions to Oil and Gas Geology of Western Pennsylvania, by J. D. Sisler, G. H. Ashley, F. T. Moyer and W. O. Hickok, 4th. 1933. 94 pp., 22 pls., 1 fig. Out of print.

M 20. Limestones of Pennsylvania, by B. L. Miller. 1934. 729 pp., 41 pls., 34 figs. $2.00.